Risk Management for the Implementation of Energy Efficient & Renewable Technologies in Australian Green Office Buildings

A thesis submitted in fulfillment of the requirements for the degree of

Doctor of Philosophy

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DECLARATION

I certify that except where due acknowledgment has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement data of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

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ABSTRACT

Green buildings are becoming popular these days, mainly due to the increasing governmental and public awareness of the need to reduce the impacts of global warming caused by the production of greenhouse gas emissions and the consumption of natural resources. Paradoxically, green buildings are not becoming as common as researchers/governments had hoped. Certain types of technologies, such as energy efficient and renewable technologies (EERTs), are used in green buildings in order to help them become more environmentally-friendly. This research focuses on four main categories of energy related technologies, including two energy efficient categories which are related to heating, ventilating, and air conditioning (HVAC) and lighting systems, and two renewable energy categories which are related to solar and wind resources. A total of nine technologies are selected for study within these four categories. Under the HVAC category there are four technologies: radiant systems, chilled beams, underfloor air distribution systems, and night purge and natural ventilation. Under the lighting category there are two technologies: energy efficient light bulbs and motion sensors. Under the solar category there are two technologies: photovoltaic panels and thermal heating systems. The single technology under the wind category is wind turbines.

Unfortunately, these technologies are relatively new and may present many risks during their implementation lifecycle for different project stakeholders. This research focuses on identifying and managing the critical risks influencing the application of EERTs in Australian green office buildings. The data collection methods consist of questionnaires, interviews and case studies. The questionnaires resulted in the identification of 14 critical risks for EERTs implemented in Australian green office buildings. They also revealed that the owners of these technologies are the most affected by the risks of EERTs and the operational stage of the lifecycle is the most likely phase of occurrence for these risks. The interviews resulted in the identification of 36 different measures to manage the 14 critical risks of EERTs. Furthermore, the research identifies the persons to manage these critical risks and the lifecycle stages at which to take action against these critical risks. The research results also disclose 37 causes and 18 impacts of these critical risks. The main purpose of the case studies is to validate the framework on two six star certified Australian green office buildings and improve the framework by practical experience. The final outcome of this research is the creation of a framework for the critical risk management of the implementation of EERTs in Australian green office buildings. This research will provide guidance to and enable informed decisions by industry practitioners and stakeholders in implementing EERTs in Australian green office buildings. This research is the first of its kind and lays the foundations for future related research.

PUBLICATIONS

Peer reviewed conference papers:

- Ibrahim Mosly and Guomin Zhang 2010, "Review of risks for the implementation of energy efficient and renewable technologies in green office buildings", *Proceedings of the Sustainable Building Conference*, Wellington, New Zealand, May 26 – 28, 2010.

- Ibrahim Mosly and Guomin Zhang 2010, "Study on risk management for the implementation of energy efficient and renewable technologies in green office buildings", *Proceedings of the Transition to Sustainability Conference*, Auckland, New Zealand, November/December 30 – 03, 2010.

- Ibrahim Mosly, Guomin Zhang and Sujeeva Setunge 2011, "Identification of critical risks influencing the application of energy efficient and renewable technologies in Australian green office buildings: Preliminary findings of a survey", *Proceedings of the 25th International Project Management Association (IPMA) World Congress*, Brisbane, Australia, 9-12 October 2011.

- Ibrahim Mosly, Guomin Zhang and Sujeeva Setunge 2011, "Managing critical risks of energy efficient and renewable technologies implemented in Australian green office buildings", *Proceedings of the World Renewable Energy Congress*, Bali, Indonesia, 16-20 October 2011.

Journal article under review:

- Ibrahim Mosly, Guomin Zhang and Sujeeva Setunge 2012, “Critical risks influencing the application of energy efficient and renewable technologies in Australian green office buildings”, *Energy and Buildings*, August, 2011.

- Ibrahim Mosly, Guomin Zhang and Sujeeva Setunge 2012, “Exploring risks of energy efficient and renewable technologies implemented in green office buildings”, *International Journal of Sustainable Development*, February, 2012.

KEYWORDS

Risk management, Lifecycle, Stakeholders, Energy efficient technologies, Renewable energy technologies, Green office buildings, Australia.

ABBREVIATIONS

Energy efficient and renewable technologies:	EERTs
Heating, ventilating, and air conditioning:	HVAC
Chilled beam:	CB
Radiant system:	RS
Underfloor air distribution:	UFAD
Night purge and natural ventilation:	NV
Energy efficient light bulb:	EELB
Motion sensor:	MS
Photovoltaic panel:	PV
Solar thermal system:	ST
Wind turbine:	WT

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CHAPTER ONE: INTRODUCTION

1.1 Research Background

Australia has the highest production of greenhouse gas emissions per capita among OECD countries and is one of the highest producers of these gases in the world (Garnaut, 2008). In 2006, Australia's per capita greenhouse gas emissions totalled 28.1 tonnes, while the average in OECD countries in 2005 was approximately 14.9 tonnes (Garnaut, 2008). Thus, Australia's greenhouse gas emissions per capita are around double the average OECD countries and more than four times the average amount for the world (Garnaut, 2008). Furthermore, it is forecast that total greenhouse gas emissions in Australia will reach 1065.5 Mt CO_2 by 2050 and almost 2000 Mt CO_2 by 2100, compared with 576 million tonnes in 2006 (Garnaut, 2008). These figures present the high emissions of greenhouse gas in Australia in the present and long term, and urgent measures are required to address them.

One of the major contributors to greenhouse gas emissions is the building sector, including both residential and commercial buildings (CoIE, 2007). This sector accounts for almost one quarter of the national greenhouse gas emissions (CoIE, 2007). This indicates the significance of greenhouse gas emissions in the Australian building sector. In terms of electricity generation in Australia, 93% is generated from fossil fuels, including coal, gas and oil (Copeland, 2010). The electricity consumption of Australian commercial buildings is responsible for 89% of greenhouse gas emissions (AGO, 1999). Office buildings are responsible for 26% of the total greenhouse gas emissions in the

Australian commercial building sector (Langdon, 2008), and greenhouse gas emissions are expected to increase by 3 to 4% each year in this sector (NABERS, 2010).

The greenhouse gas emissions of the building sector can be reduced by 30-35% whilst accommodating growth in the total number of buildings by 2050 (CoIE, 2007). This reduction in greenhouse gas emissions is achievable by using today's technologies to significantly reduce the energy consumption in both residential and commercial buildings to achieve the same services (CoIE, 2007). These energy-related technologies such as energy efficient and renewable technologies (EERTs) can be implemented in buildings, transforming them into what are now called green buildings.

According to a number of independent studies, buildings that are certified to be green by green building councils can reduce energy consumption by 85%, reduce portable water usage by 60%, and send 69% less waste to landfills when compared to non-certified buildings globally (WGBC, 2009). On average, a certified Australian green office building can save 60% on emissions compared to traditional Australian office buildings (WGBC, 2009). Fossil fuel use is reduced in green buildings through energy efficiency and on-site renewable energy (GBCA, 2010b), and as a result less greenhouse gas emissions are produced. These statistics have encouraged the spread of green office buildings in Australia. For instance, Green Star Certification has been approved for 11% of Australia's central business district (CBD) office space (GBCA, 2010a). The Green Building Council of Australia (GBCA) certified 71 green buildings from the day of its establishment until the end of 2008 (GBCA, 2009b). Furthermore, green buildings are currently capturing around 30% of the total new building market (Bowman and Wills, 2008).

It is common for the application of new green technologies to carry uncertainty and risk (Lam et al., 2010). Unfortunately, this is affecting the spread of these technologies in green buildings. As a result, on the one hand green buildings are gaining momentum on the other hand EERTs are not. For instance, underfloor air distribution systems which are an alternative for general office space fitout have not been widely accepted, mainly in Australia (Zhang and Yang, 2006). Similarly, wind turbines face many challenges, where the biggest challenge is the public acceptance and confidence in the technology (Dayan, 2006). Some small wind turbine manufacturers and practitioners even go further by not recommending the implementation of these technologies on buildings (Dutton et al., 2005). In Australia, the Green Star tool is used as a comprehensive, national, voluntary environmental rating scheme that assesses the environmental design and construction of buildings (GBCA, 2010b). In general, the tool depends on a weighted points score that is given to a building in nine environmental impact categories (GBCA, 2010b). These categories are: 1. management, 2. indoor environment quality, 3. energy, 4. transport, 5, water, 6. materials, 7. land use and ecology, 8. emissions, 9. innovations (GBCA, 2010b). The more points the building is awarded, the higher the Green Star rating it achieves (GBCA, 2010b). Because only four out of the nine environmental impact categories can be related to EERTs, building developers and owners are focusing more on the other categories to achieve an easier certification. This is done to secure the building rating and at the same time is a safer way of achieving certification, rather than the more risky option with the application of green technologies.

To reduce or eliminate uncertainty and risk, more research on risk management for new EERTs should be carried out. The risk management process has seven major elements: communicate and consult, establish the context, identify risks, analyse risks, evaluate risks, treat risks, and monitor and review (AS/NZS, 2004). The adoption of this process will provide benefits such as fewer surprises, the exploration of opportunities, improved planning, performance, and effectiveness, improved information provision and decision making, and enhanced reputation (AS/NZS, 2004). Other important pieces research in areas such as stakeholder analysis and lifecycle asset management can also be used to strengthen the risk management process. For instance, stakeholder analysis can be used to identify those stakeholders who are affected by EERT risks and the stakeholders who are able to manage them. Moreover, lifecycle asset management can illustrate the lifecycle stages at which the risks are likely to occur and the lifecycle stage of remedial action against these risks. As a result, risks can be reduced or even eliminated and in turn implementation rates will increase.

1.2 Research Significance

This research will contribute to the existing knowledge of green buildings as it will increase governmental and public (owners, contractors, engineers, and other lifecycle stakeholders) awareness of the potential risks pertaining to the EERTs implemented in Australian green office buildings, as well as the methods to manage these critical risks.

The research outcome will help industry practitioners recognize the generic risks of EERTs as well as some of the specific risks of these technologies. At a broader level, it will also assist in the development of a framework to provide informed advice to project stakeholders in using green building technologies. The final outcome of this research will be a comprehensive framework that is able to answer all of the research questions.

1.3 Research Problem

A generic research problem led to the investigation of this topic, as it represents the foundation of this research. The research problem is as follows:

Energy efficient and renewable technologies (EERTs) have been available in the market for a while now but appear to be not applied widely. What are the risks pertaining to EERTs which obstruct their wide application in Australian green office buildings?

1.4 Research Questions

Six questions that are derived from the research problem form the basis of this research. The questions are listed below:

1. *What are the critical risks that stakeholders may face when using EERTs in Australian green office buildings?*
2. *Do different industry practitioners share the same opinions of the risks associated with EERTs implemented in green office buildings?*
3. *For each critical EERT risk, who are the affected stakeholders and who are the stakeholders responsible for treatment?*
4. *For each critical EERT risk, what are the lifecycle stages of risk occurrence and what are the lifecycle stages of action against these critical risks?*
5. *How can these critical risks be managed in the process of implementing EERTs for green office buildings?*
6. *How can green office building stakeholders be well guided in managing EERTs critical risks in a preventative manner?*

The first question explores the critical risks of EERTs used in Australian green office buildings. These critical risks will be selected from a range of risks gathered from an extensive literature review as well as others proposed by industry experts during the questionnaire survey process. The second question investigates the perceptions of different industry experts on the risks of EERTs and whether different expert groups have different opinions on these risks. The third question will identify the stakeholders affected by EERTs' different risks and the stakeholders responsible for treatment. The affected stakeholders are those who are impacted by EERT risks, while the responsible stakeholders are those who are able to find solutions and manage the EERT risks. The fourth question will explore the lifecycle stages at which these EERT risks are likely to occur and will also point out the lifecycle stages of action against the critical risks of EERTs. The fifth question will examine ways to manage critical EERT risks effectively. The final question seeks the development of a framework that provides guidance to green office building stakeholders against EERTs critical risks.

1.5 Research Objectives

Six main objectives were established for this research in accordance with the research questions. The objectives are summarized below:

1. Identify critical risks pertaining to the design, construction and throughout lifecycle of EERTs in Australian green office buildings.
2. Explore whether different industry expert groups have different perceptions of these risks.
3. Recognize the affected and responsible stakeholders for EERTs critical risks in Australian green office buildings.
4. Classify the lifecycle stages at which the critical risks of green office buildings EERTs occur and the lifecycle stages of action against these critical risks.
5. Propose appropriate approaches to manage the critical risks identified.

6. Develop an integrated framework encapsulating critical risks and solutions to provide informed advice to stakeholders.

The first objective is related to the first question of this research. It aims to select the critical risks of EERTs implemented in green office buildings from a broad list of risks gathered from the literature review. These critical risks will be chosen on the basis of a quantitative data analysis of a questionnaire distributed to industry experts.

The second objective is to examine different industry experts' perceptions of EERT risks and establish whether they have similar or different opinions. Some risks may be attributed to some stakeholders and if not managed well, may cause damage.

The third objective of this research is to recognise the stakeholders who are affected by these critical risks and the stakeholders who are responsible for managing these critical risks. This will assist EERTs stakeholders to have a basic awareness of the influence of these risks on certain stakeholders and the accountability of others.

The fourth research objective is to explore the lifecycle stages at which the critical risks of green office buildings EERTs occur, and identify the lifecycle stages of action to counter these critical risks. This objective is important because it will demonstrate to the stakeholders when to expect the risks to occur and when to manage them.

The fifth research objective is the most significant, as it will give a clear indication to all green office building stakeholders on how to deal with these critical risks in order to eliminate them or minimize their impact.

Finally, the last objective is to create a framework that integrates the answers to all six research questions, making the picture comprehensive and apparent to the stakeholders in relation to green office buildings' EERTs critical risks.

1.6 Overview of Research

This research follows an exploratory approach by using a combined quantitative and qualitative methodology. The data were collected in four stages: a literature review, questionnaires, semi-structured interviews, and case studies. A model that illustrates the research process in the form of inputs and outputs is presented in Figure 1-1.

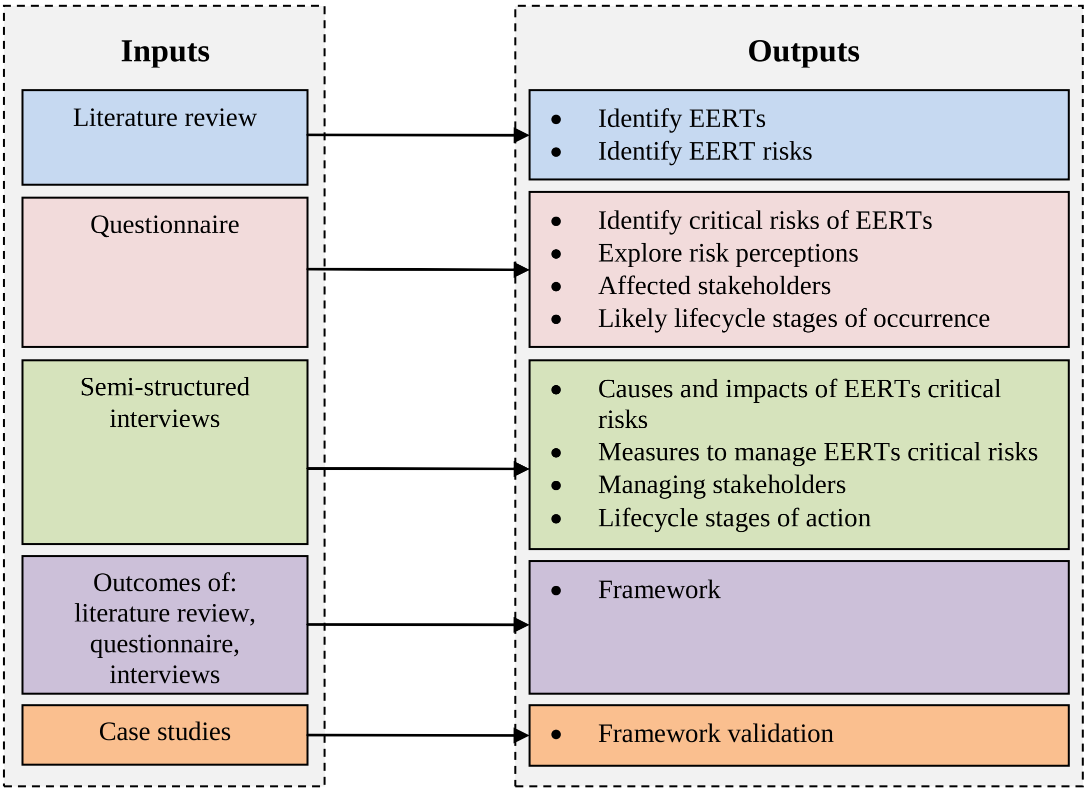

Figure 1-1: Research process

The research process started with a literature review to (1) pinpoint commonly-implemented EERTs in Australian green office buildings and (2) identify their risks. These technologies form the bases of the research as they represent EERTs in the context of Australia. After the literature review a quantitative analysis was carried out on the questionnaire feedback. This was undertaken to narrow the list of risks and identify those risks that are considered critical. In addition, the differences in risk perception of different industry practitioners with respect to each risk for each technology were explored. Moreover, stakeholders affected by EERTs risks were recognized. Furthermore, the likely lifecycle stages of risk occurrence were also identified in the analysis. Following the questionnaire, a qualitative analysis was carried out on the responses to the semi-structured interviews. Here, causes and impacts of EERTs critical risks were revealed and measures to manage the critical risks of EERTs identified. Identification of the managing stakeholders was also carried out and the lifecycle stages of action against EERTs critical risks were identified. Following the semi-structured interviews, a framework incorporating all of the outcomes of the previous steps was established. In the final stage of the research, the framework was validated on two Australian green office buildings.

1.7 Research Scope

Representing a significant part of green buildings, EERTs play an important role in achieving the objectives of these buildings. The present research is limited to exploring the risks of EERTs in Australian green office buildings, and the widely used EERTs in Australian green office buildings will represent the foundation of the study.

Four categories were selected to represent the nine EERTs. These categories are HVAC, lighting for energy efficient technologies, and solar and wind for renewable energy technologies. Their selection was made based on their importance in terms of the high energy consumption of HVAC and lighting systems, and their adaptability on buildings and their being a good source of energy production for solar and wind resources. Only those EERTs that are implemented in a wide range of Australian office buildings were selected, in order to make this research reflect those EERTs that are most commonly used in Australian green office buildings by industry practitioners.

This research will focus on three main aspects of the research literature: 1. Risk management, 2. Stakeholder analysis, and 3. Lifecycle asset management. These theories are widely used in research related to civil engineering, and the basic concepts and milestones of these theories will be used to develop the research framework.

1.8 Overview of Chapters

This thesis consists of seven chapters. A brief summary of each chapter is as follows:

Chapter 1 has provided a research background for the implementation of EERTs in Australian green office buildings, and presented the research significance, the research problem, the research questions, the research objectives, and the scope of the research. A brief overview of the research methodology has also been outlined.

Chapter 2 presents the research completed to date in the field of EERTs and addresses the relevant literature related to the research topic. It starts by introducing green buildings and highlights the implementation of EERTs in them. It then presents the literature related to risk management in general. A description of the EERTs used in this research and their benefits is also provided, followed by a comprehensive review of the risks of these EERTs. Stakeholder theory and analysis is introduced and its relevance to the research is explained. Lifecycle asset management is then introduced and its relevance to the research is detailed. At the end of the chapter, the research gap is identified.

Chapter 3 details the research methodology and includes the research design, research process, data collection methods, development of data collection methods, data analysis, and the formulation of the research framework.

Chapter 4 presents the questionnaire analysis and findings. The feedback from industry practitioners is grouped into four parts and categorized accordingly for analysis Part one is related to the identification of EERTs critical risks; Part two to the exploration of risk perceptions by the different industry groups; Part three considers the identification of the affected stakeholders; and Part four aims to ascertain the likely lifecycle stages of risk occurrence. The questionnaire findings are presented at the end of the chapter.

Chapter 5 presents the analysis and results of the semi-structured interviews. The feedback of industry practitioners is grouped into five parts for analysis Part one reveals the causes of EERTs' critical risks; Part two reveals the impacts of EERTs critical risks; Part three identifies measures to manage the critical risks of EERTs; Part four examines the identification of the managing stakeholders of EERTs critical risks; and Part five identifies the lifecycle stages of action against EERTs critical risks. The findings of the semi-structured interviews are presented at the end of the chapter.

Chapter 6 presents the research framework and its guide as well as the framework validation process. The framework is divided into six steps; communication and consultation, establish the context, identification, risk analysis and evaluation, treatment, and monitor and review.

Chapter 7 contains the conclusions, the contribution of the study to knowledge in the field, the benefits of Australian study to other countries, the study limitations, and suggestions for future research.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

In this chapter, a review of the literature relevant to the questions and objectives of the research is presented. The review includes the following topics: green buildings, risk management, energy efficient and renewable technologies, risks of energy efficient and renewable technologies, stakeholder theory and analysis, lifecycle asset management, and identification of research gaps.

The literature on green buildings in the Australian context is discussed in first part of this chapter. It defines green buildings and presents information on the green building councils, outlines the history of green buildings in Australia, discusses the spread of green buildings, and describes the benefits of green buildings, and defines green office buildings. An overview of risk management is then provided, including definitions of risk followed by the benefits of carrying out the risk management process and details of two widely-adopted methods of risk management are set out. This section is followed by a review of the goals of EERTs, the technologies selected as the basis of the present research and their advantages and disadvantages. The risks of these technologies are then discussed, including risk categorization and the risks of EERTs. Stakeholder theory and analysis as well as lifecycle asset management are then presented, with emphasis on their relevance to this research. Finally, the identification of research gaps is discussed.

2.2 Green Buildings

Green buildings practice and green buildings have been defined in many different ways. For instance, the United States Environmental Protection Agency defines green building as “The practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort” (EPA, 2010). According to Montoya (2011), a simple and specific definition of green buildings is “the implementation of sustainable design”. He believes that implementing thoughtful practices can mitigate the major impact of the construction process on the environment (Montoya, 2011). These practices include (Montoya, 2011):

- Decreasing and recycling construction waste,
- Managing noise, light and air pollution throughout construction,
- Protecting and repairing natural habitation,
- Controlling storm water runoff pollution and erosion,
- Ensuring the efficient operation of buildings once they are complete,
- Using regionally-harvested and manufactured materials with recycled content,
- Selecting low-emitting building materials,
- Managing the harmful emissions of construction equipment and vehicles.

Moreover, the GBCA defines green buildings as those buildings that decrease or totally eliminate harmful impacts on the environment and occupants, while addressing the following approaches during design, construction and operation (GBCA, 2008):

- Efficiency in energy consumption,

- Conservation of water,
- Reduction of greenhouse gas emissions,
- Capability of waste avoidance, reuse and recycling,
- Prevention of pollution, such as noise, water, air, soil and light,
- Enhancement of biodiversity,
- Reduction in the consumption of natural resources,
- Contribution to a productive and healthier environment,
- Provision of spaces which are flexible and adaptable.

These green building definitions agrees that green buildings prevents or reduce the negative impacts of building construction and operational activities on the environment. The GBCA green building definition goes further and includes the enhancement of a productive and healthier environment for building occupants and providing spaces that are flexible and adaptable as part of the definition.

2.2.1 Green building councils

The World Green Building Council (WorldGBC) was established in November of 1999. Its objective was to completely convert building practice from conventional to sustainable in order to guarantee an enhanced future for our world. Its mission includes (WGBC, 2009):

- Promote the significant role of green buildings in mitigating global climate change, ease successful communication, spread best practice, and encourage collaboration among councils, countries, and industry leaders,
- Establish successful Green Building Councils (GBCs) and ensure that they have sufficient resources to prosper within their particular markets,

- Support successful building performance rating tools and encourage the development of obligatory minimum standards for energy efficiency in buildings,
- Design a unique internship program and an innovative university-accredited course in order to develop the capacity of the next generation of green building professionals.

By 2010, 82 countries were members of the WorldGBC (WGBC, 2010). This consisted of 20 established GBCs, nine emerging GBCs, 27 prospective GBCs, and 26 associated groups (WGBC, 2010).

The GBCA was established at the end of 2002 (GBCA, 2008). Its mission is to drive the implementation of green building practices through market-based solutions and to define and develop a sustainable property industry in Australia (GBCA, 2008). In January 2004, the first Green Star Accredited Professional course was held (GBCA, 2011b). After seven years of effort, more than 18,500 people have gained the skills to effectively apply the Green Star tools to benchmark and scope their building design and construction (GBCA, 2011b).

2.2.2 History of green building in Australia

The green building movement started in Australia with the launch of the 2000 Sydney Olympic Games, which was also called the Green Games (GBCA, 2006). The launch of the Australian Building Greenhouse Rating (ABGR) occurred in 2001, followed by the establishment of the Green Building Council of Australia in October 2002 (GBCA, 2006). The first version of the Green Star rating system was released in 2003 (GBCA, 2006). In September 2004, 8 Brindabella Circuit was Australia's first official certified green building with a five star rating (GBCA, 2006). In 2005, the South Australian and Victorian governments announced that all new offices built or leased by the governments must achieve a 5 Star Green Star rating for South Australia and a 4 Star Green Star rating for Victoria (GBCA, 2006).

2.2.3 The spread of green buildings

The GBCA has certified 71 Australian green buildings from the day of its establishment until the end of 2008 (GBCA, 2009b). Green buildings are currently capturing around 30% of the total new Australian building market (Bowman and Wills, 2008). Furthermore, in 2010, Green Star certification was approved for 11% of Australia's central business district (CBD) office space (GBCA, 2010a). In the United States of America, research shows that the market value of commercial and institutional green buildings represents 2% of the market size. It also forecasts that this percentage will dramatically increase to 20%-25% by 2013 (Bernstein and Russo, 2008).

2.2.4 Benefits of green buildings

In Australia, it is expected that more than 251,500 green collar jobs will be created in the property and construction industries, which represents 45 percent of all of the jobs forecast to be created by 2025 (GBCA, 2009b). Green buildings can provide several benefits to their stakeholders, including the following:

- Enhanced marketability,
- Greater tenant attraction and retention,
- High return on investment,
- Improved health and productivity and reduced churn costs,
- Increased in rents,

- Lower operating costs,
- Reduced risks.

Each of these benefits is discussed in the following sections.

2.2.4.1 Enhanced marketability

Green buildings provide better marketability (GBCA, 2008). Generally, the public perceives green buildings as modern, dynamic and altruistic, which in turn give the organizations associated with these buildings extra benefits through the pride, satisfaction and well-being of their employees (GBCA, 2008). Furthermore, the desire for publicity is a strong motivator, especially when green is emphasised everywhere, including news broadcasts and TV advertisements (Bernstein and Russo, 2008). Stakeholders demand this publicity in return for bringing their company more business and a better public image (Bernstein and Russo, 2008).

2.2.4.2 Greater tenant attraction and retention

Green buildings offer greater tenant attraction and fewer vacancy periods (GBCA, 2008). Tenants who are interested in a cleaner, innovative, and work-friendly environment often demand sustainable buildings (Frej, 2005). State governments since 2006 have largely driven tenant demand, requiring a number of green building standards (GBCA, 2008). In 2008, the demand for green buildings increased from government and industry (GBCA, 2008). Due to the fact that green buildings result in higher levels of tenant satisfaction, this leads to higher levels of tenant retention, shorter downtime between leases, and lower retaining expenses for landlords (Frej, 2005). According to an online staff survey carried out by Bond University, 93% of employees find it important to work in a green office

(BU, 2008). The survey was also reinforced by business managers, 66.6% of whom believed that renting or owning a green building helped to attract and/or retain their employees (BU, 2008). The frequency by which a building occupant moves internally or externally is known as churn (GBCA, 2008). Another definition of churn is the percentage of the organization that relocates its job location during a year (Harrison et al., 1998). Churn can be reduced in green buildings due to the enhanced occupant comfort and satisfaction (GBCA, 2008).

2.2.4.3 High return on investment

Green buildings provide higher returns on the asset and increased property values (GBCA, 2008). Green buildings offer better return on investment compared to traditional buildings according to research conducted in the United States of America (Bernstein and Russo, 2008). The results shows that in 2008 the industry expected green buildings to have a 9.9% higher return on investment than traditional buildings (Bernstein and Russo, 2008).

2.2.4.4 Improved health and productivity

Studies have shown that health improvement is linked to green buildings (Bernstein and Russo, 2008). This includes lower rates of asthma amongst nurses in green hospitals, lower absenteeism and better concentration as well as bodily growth among students, and 39% lower average number of sick days as well as 44% reduction in staff monthly health care costs (Bernstein and Russo, 2008). Sustainable features incorporated into schools, offices, and hospitals can improve students', tenants', and staff performance (Bernstein and Russo, 2008). A study of Council House 2 (CH2) which is one of Melbourne's 6 Green Star certified buildings, has revealed that the productivity level has significantly improved compared with Council House 1 (CH1), as 75% of the building occupants have rated the building as having positive or neutral effect on productivity, while only 39% gave the same rating to the old CH1 building (Paevere and Brown, 2008).

2.2.4.5 Increased in rental

Green buildings have the potential to increase rent (Bernstein and Russo, 2008), and some tenants are prepared to pay the rental costs of attaining green star certification (Bowman and Wills, 2008). According to research undertaken in the United States of America, green building rental is forecast to increase by 6% compared to traditional buildings (Bernstein and Russo, 2008).

2.2.4.6 Lower operating costs

Lower operating costs are a key benefit to a green building's owner or facility manager (GBCA, 2008). Reducing the operating costs of a building and equipment can be achieved by energy efficiency, which in turn saves money (GBCA, 2008). Research in the United States of America shows that most companies participating in the research anticipated lower operating expenses for green buildings (Bernstein and Russo, 2008). Their expectation for savings were higher in 2008 compared to 2005, indicating a maturing industry with increasing confidence in the payback of green building (Bernstein and Russo, 2008). A green realestate project will decrease utility expenses by as much as one third when compared with a traditional construction, reflecting a clear benefit in terms of operating cost savings (Frej, 2005).

2.2.4.7 Reduced risks

Green buildings offer the ability to reduce liability and risk (GBCA, 2008). They offer to reduce a variety of risk factors, including marketing, financing, and securing political authorization to development (UI, 2008). The design and construction of green buildings minimize sources of environmental risks, resulting in less probability of green buildings being a source of environmental risk compared to traditional buildings (Frej, 2005). For instance, risk of sick building syndrome litigation due to air quality issues can be reduced by green buildings, because green buildings promote exceptional air quality (Lucuik, 2005). Furthermore, the certification of a green building can provide some sort of security against future lawsuits through third party verification of installed measures (USGBC, 2011). Moreover, green buildings receive faster permitting, planning approvals or special permit assistance which helps in reducing risks (UI, 2008).

2.2.5 Green office buildings

Although the main purpose of an office building is to provide a comfortable, healthy, and productive environment for the workers, costs, both capital and operational, play an important part in decision-making for design, fitting out, and other aspects of building (Burton, 2001). An office building can be simply defined as a large building that contains offices (Cambridge, 2011). In more detail it can be defined as "A single or multi-storey structure designed for the conduct of business, generally divided into individual offices and offering space for rent or lease" (IREM, 2003). Office buildings can be classified into three types A, B, and C (IREM, 2003). Class A buildings demand the highest rents and are the most attractive in their markets. Class B buildings require average rents and offer fair to good facilities and services. Class C buildings are available for lower than average rents and provide very basic facilities and services (IREM, 2003).

Green office buildings combine the features of green buildings and office buildings, leading to a unique blend that services a wide range of businesses and contributes to sustainable solutions for the occupant and the environment. Although there is no rigid definition of green offices, certain certification systems such as the Leadership in Energy and Environmental Design (LEED) and the Building Research Establishment Environmental Assessment Methods (BREEAM) offer guidelines and ways of measuring how sustainable a building is (Frej, 2005).

2.3 Risk Management

Risk can occur in any of our daily activities, such as driving a car or managing a project. Managing these risks is done continuously, either consciously or non-consciously (AS/NZS, 2004). In dealing with complicated projects like green building projects, a well-structured approach to risk management should be implemented.

2.3.1 Definition of risk

The term risk has been defined by several authors. Generally, these authors can be grouped into two categories: (1) those who define risk as having negative connotations (Modarres, 2006; Rowe, 1977) and (2) those who define risk as having both positive and negative connotations (Cretu et al., 2011; Smith, 2002). According to Modarres (2006), risk from an engineering viewpoint is associated with the exposure of recipients to hazards and can be articulated as the combination of the probability and consequence of the hazard (Modarres, 2006). For this author, hazard is defined as the potential for an undesired loss to occur without consideration to either the frequency or the probability of this loss, such as flood, wildfire, asbestos and high voltage (Modarres, 2006). Similarly to Modarres (2006), Rowe (1977) defines risk as "the potential for unwanted or negative consequences of an event or activity". On the other hand, Smith (2002) states that "risk is adverse but an unknown by its nature can have both positive and negative effects". Furthermore, some authors define risk as an uncertain outcome which may be positive or negative, where negative risk is defined as a threat and positive risk as an opportunity (Cretu et al., 2011).

Barriers are generally defined as follows "a fence or other obstacle that prevents movement or access" (OD, 2011). Risks are related to barriers as they can also be defined as obstacles that carry out the role of containing, removing, neutralizing, preventing, mitigating, controlling or warning the release of a risk (Modarres, 2006). Risk occurrence depends on the barrier's performance. If the performance of the barrier is sufficient, then the risk will not be exposed or will be exposed in a minimal manner. On the other hand, if the barrier's performance is not sufficient, consequences and losses might occur due to the exposure (Modarres, 2006).

From the preceding we can conclude that risks and barriers are related and that barriers can be a source of risks if they fail to function properly. Moreover, most challenges, impediments, issues, and limitations can also be treated as risks. This is due to the fact that they have variable occurrence possibilities and consequence levels. In the present research, risk will be taken as having negative connotations.

2.3.2 Risk management process

Many organizations have developed their own risk management processes but eventually they all serve the same purpose of managing risks. Two of the most commonly used risk management processes have been established by the Project Management Institute and the Australian/New Zealand Technical Committee, which are the project risk management chapter from the Project Management Body of Knowledge (PMBOK) guide and the Australian/New Zealand (AS/NZS) 4360:2004 respectively.

2.3.2.1 Project risk management

In the project risk management chapter of the PMBOK guide, the risk management process is divided into six steps: risk management planning, risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning and risk monitoring and control (PMI, 2004). These are discussed in the following sections.

Risk management planning

In this step of the risk management process, a decision is made on how to approach and perform the risk management tasks for a certain project (Burtonshaw-Gunn, 2009; PMI, 2004). Risk management planning is significant to ensure that the level, type and visibility of risk management are adequate for the risk and the importance of the project to the organization (Burtonshaw-Gunn, 2009), so that sufficient resources and time are provided for risk management activities (PMI, 2004).

Risk identification

The determination of which risks might affect the project is done in the risk identification step as well as documenting the characteristics of these risks (Burtonshaw-Gunn, 2009; PMI, 2004). As the project progresses through its life cycle, new risks may appear and this is why the risk identification process is an iterative process (PMI, 2004).

Qualitative risk analysis

Prioritising the identified risks for further action is carried in the qualitative risk analysis step (Burtonshaw-Gunn, 2009; PMI, 2004). The organizations project performance can be enhanced successfully by focusing on high priority risks (PMI, 2004). Qualitative risk analysis measures the priority of recognized risks by using factors such as probability of occurrence, impact on project, time frame and risk tolerance of project constraints, which are cost, schedule, scope and quality (PMI, 2004).

Quantitative risk analysis

After the risks are prioritised by the qualitative risk analysis as having a possible and considerable impact on the project's competing demands, quantitative risk analysis is performed (Burtonshaw-Gunn, 2009; PMI, 2004). Here, risks events are analysed and numerical rating are assigned to them (Burtonshaw-Gunn, 2009; PMI, 2004).

Risk response planning

In the risk response planning step, alternatives are developed and actions determined to improve the chances of success and reduce threats to the project objectives (PMI, 2004). Identifying and assigning one or more risk response owners is done in this step, in order to take responsibility for each agreed and funded risk response (PMI, 2004). Risks are addressed in the risk response planning step by their priority, adding resources and activities into the budget, schedule and project management plan as required (PMI, 2004). Several risk response strategies are available for the project team, for each risk, they must select the strategy that is most likely to be effective (Burtonshaw-Gunn, 2009).

Risk monitor and control

In the risk monitoring and control step, newly arising risks are identified, analysed and planned for (Burtonshaw-Gunn, 2009; PMI, 2004). Previously identified risks and those on the watch list are kept on track (Burtonshaw-Gunn, 2009; PMI, 2004). Existing risks are reanalysed, trigger conditions and residual risks are monitored, and risk response execution is reviewed while evaluating the effectiveness (PMI, 2004). In risk control, changes including alternative strategies, implementing a contingency plan, taking corrective action(s), or even the replanning of the project might occur (Burtonshaw-Gunn, 2009).

2.3.2.2 AS/NZS 4360:2004

According to the Australian/New Zealand Risk Management Guideline Companion, the risk management process contains seven main elements: communicate and consult, establish the context, identify risks, analyse risks, evaluate risks, treat risks and monitor and review (AS/NZS, 2004). This can be summarized in Figure 2-1.

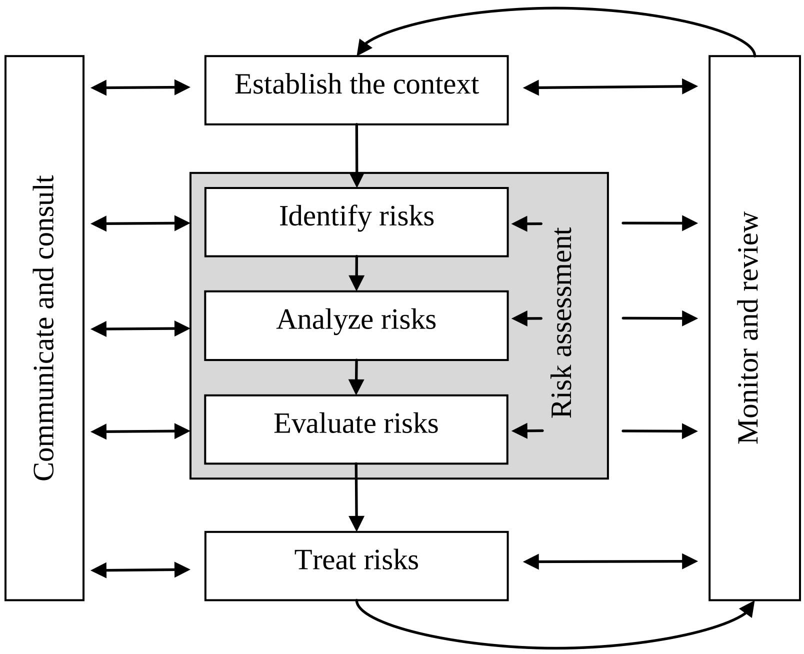

Figure 2-1: Risk Management Process (AS/NZS 2004)

Communication and consultation

Risk communication refers to the process of exchanging both information and opinions between the different parties that engage in many messages regarding the nature of risk and its management (AS/NZS, 2004), whereas consultation is a process that is carried out before making a decision or knowing the action on a particular issue between an organization and its stakeholders (AS/NZS, 2004).

Establish the context

Establishing the context is done by setting the boundaries in which the risk will be managed and defining the scope of the risk management process (AS/NZS, 2004).

Risk identification

The main role of the risk identification step is to create a comprehensive list of risk sources and events that might affect the achievement of the identified objectives in the context (AS/NZS, 2004).

Risk analysis

The importance of the risk analysis step in the risk management processes is to create a better understanding of the risk, give an indication of the need to treat the risk and the most suitable cost-effective approach to the treatment (AS/NZS, 2004).

Risk evaluation

In this step, decisions on the outcomes of the risk analysis step are taken into account (AS/NZS, 2004). The decisions are focused on whether these risks require treatment and the priority of treatment (AS/NZS, 2004).

Risk treatment

In the risk treatment step, a variety of risk treatment options are identified and assessed and a treatment plan is prepared and implemented (AS/NZS, 2004).

Monitoring & review

Monitoring and reviewing the risks on an ongoing basis is very important to make sure that the risk management plan remains effective (AS/NZS, 2004).

2.3.2.3 Risk management process in the present research

The risk management process of the PMBOK and the AS/NZS 4360 provide the same outcomes. There is a slight variation in the content of each step, but the milestones of both are similar. For instance, both risk management processes define the scope and plan for the risk management activity. Furthermore, they identify, analyse, treat, and monitor and review the risks. A difference exists in the first step of the AS/NZS 4360 process where communication and consultation is emphasised, whereas in the PMBOK process these are not emphasised as much, being considered part of the planning step. Also, the PMBOK has separate analysis steps, qualitative and quantitative, whereas in the AS/NZS 4360 they are both joined in the analysis step. Moreover, in the AS/NZS 4360 a step of risk evaluation is made, whilst in the PMBOK this step is included in the risk response planning step.

An important objective of the present research is to create a critical risk management framework for EERTs implemented in Australian green office buildings. This framework will assist stakeholders in making decisions on EERTs critical risks. Because this framework is designed for the Australian environment and Australian professionals are more familiar with the AS/NZS 4360, and because of the similarities between the two processes, the AS/NZS 4360 will be used in the framework of this research.

2.4 Energy Efficient & Renewable Technologies

To make this research as comprehensive as possible, specific EERTs were chosen for inclusion. This will lead to an inclusive risk list that contains both the general risks of all EERTs and the risks of these selected EERTs. Hence, more EERT risks can be examined in the research framework. The selection of these energy efficient and renewable technologies was done following an intensive literature review and industry consultation. The study of 5 and 6 star rated green office buildings such as the CH2 building in Melbourne was the main source of information.

A number of Australian green office buildings were evaluated in order to ascertain what types of EERTs were used in them. These buildings were all rated with 5 or 6 green stars and with EERTs implemented. Table 2-1 presents a summary of the EERTs applied in each of the green office buildings selected.

Table 2-1: EERTs used in randomly selected Australian green office buildings

Green office building	EERTs implemented
CH2, Melbourne, VIC, 6 stars (CoM, 2009a), (COM, 2009b), (CoM, 2009c)	Lighting: T5 fluorescent lighting, motion sensors, timber shutters
	Solar: Solar thermal panels & photovoltaic cells
	HVAC: Night purge, underfloor air distribution, chilled beams, radiant system, and shower towers
	Wind: Wind turbines
	Gas fired co-generation plant
The Gauge, Melbourne, VIC, 6 stars (GBCA, 2009a)	Lighting: Motion sensor, efficient lighting, internal solar blinds
	HVAC: Chilled beams, radiant systems
Szencorp Building, South Melbourne, VIC, 6 stars (Gell, 2009)	Lighting: Energy efficient lighting, motion sensors
	Solar: Solar thermal, photovoltaic cells
	HVAC: Natural ventilation
Bendigo Bank, Bendigo, VIC, 5 stars (GBCA, 2009a)	Lighting: Energy efficient lighting, motion sensors, internal solar blinds
	HVAC: Underfloor air distribution
RAAF Richmond Reinvestment Project Squadron Headquarters, Richmond, NSW, 5 stars (GBCA, 2009a)	Lighting: Energy efficient lighting T5 fluorescent, motion sensors
	HVAC: Natural ventilation, automated louvers
2 Victoria Avenue, Perth, WA, 6 stars (GBCA, 2009a)	Lighting: Fluorescent lighting, motion sensors, active louvers
	HVAC: Chilled beams
	Wind: Wind turbines
235 St George's Terrace, Perth, WA, 5 stars (GBCA, 2009a)	Lighting: Energy efficient lighting, motion sensors
	HVAC: Low temperature variable air volume air conditioning coupled with high efficiency chillers
30 The Bond, Millers Point, NSW, 5 stars (GBCA, 2009a)	Lighting: T5 fluorescent lighting, motion sensors, automatic external blinds
	HVAC: Chilled beams, natural ventilation
Hume City Council Office Building, Broadmeadows, VIC, 5 stars (GBCA, 2009a)	Lighting: T5 fluorescent lighting
	HVAC: Underfloor air distribution
City Central Tower 1, Adelaide, SA, 5 stars (GBCA, 2009a)	Lighting: T5 fluorescent efficient lighting
	HVAC: Natural ventilation, chilled beams

The selection of the EERTs was made based on Table 2-1, in which a total of nine formed the basis of this study. The EERTs were categorized under four groups, two being energy efficient technologies developed for HVAC and lighting systems, and two being renewable energy technologies using solar and wind resources.

2.4.1 Goals of energy efficient and renewable technologies

Many terms were found in the literature related to EERTs, including green technologies, clean technologies, environmentally-sound technologies, sustainable technologies, and alternative technologies. The key features of these technologies can be summarised as follows:

- Less environmentally damaging than existing technologies (CEC, 2004; Guziana, 2011),
- Treat and prevent environmental damage (Guziana, 2011),
- Less polluting with fewer emissions and less waste (CEC, 2004),
- Manage resources more efficiently with reduced energy and resource consumption (CEC, 2004),
- Provide economic advantages (Clift, 1997).

These five goals of EERTs are essential factors in their successful implementation.

2.4.2 Energy efficient technologies chosen for this research

Energy efficient technologies for HVAC and lighting were selected because these two building service systems consume the major proportions of the energy used in Australian commercial buildings, being 70% for HVAC and 15% for lighting (AGO, 1999). For office buildings in particular, HVAC and lighting contribute 70% of the total building energy consumption in the United States of America, 72% in the United Kingdom, and 85% in Spain (Lombard et al., 2008). The selection of HVAC and lighting technologies was made with reference to Table 2-1 which presents a sample of Australian green office buildings and the EERTs implemented in them. Four types of energy efficient HVAC technologies, including chilled beams, night ventilation, radiant systems and underfloor air distribution were selected for the present research. Two types of lighting technologies, energy efficient light bulbs and motion sensors, were also chosen.

2.4.2.1 HVAC - Radiant systems

Radiant systems depend on the mechanism of radiant heat transfer, where heat is transferred in straight lines by electromagnetic waves that can also be reflected (ASHRAE, 2003). Basically, heat transfer takes place between surfaces or between surfaces and a source of heat (ASHRAE, 2003). The source of heat is the water that flows through the pipes (McDowall, 2007). These systems can be installed in several designs, such as (ASHRAE, 2003):

- Ceiling panels,
- Implanted tubes or fixed pipes in the ceilings, floors or walls. The tubes can be made of plastic, rubber or copper (see Figure 2-2),
- Air-conditioned floors or ceilings,
- Electric panels attached to the walls or ceilings,
- Electric mats attached to the walls or ceilings,
- Deep heat.

It is preferable to install radiant cooling and heating systems on the ceiling, so that they can imitate the natural effect of the sun and night sky (Yudelson, 2008).

Advantages

Radiant systems are silent and known for high human comfort (Yudelson, 2008). They consume less energy than traditional air-conditioning systems with average savings of 30% (Yudelson, 2008). The capital cost of radiant systems is economical when compared with other HVAC systems that require ducting work which is more expensive than small pipes (McDowall, 2007). Radiant systems are considered to be very comfortable for children and old people as they do not cause significant thermal stratification (McDowall, 2007). They also save floor or wall space as no ducting is required (McDowall, 2007).

Disadvantages

There are several disadvantages of using radiant cooling and heating systems, including the following:

- The radiant cooling system may cause significant surface condensation, which might lead to mould growth (Feustel and Stetiu, 1995; Yudelson, 2008).
- Due to the dependency of the system on the radiation mechanism, experts must be involved in the building, design and installation of these systems or operational failure may occur (Yudelson, 2008).
- Such systems are not able to respond quickly in places with fluctuating weather conditions (Yudelson, 2008).
- There is a risk of pipes freezing or leaking, which will lead to system failure (McDowall, 2007).

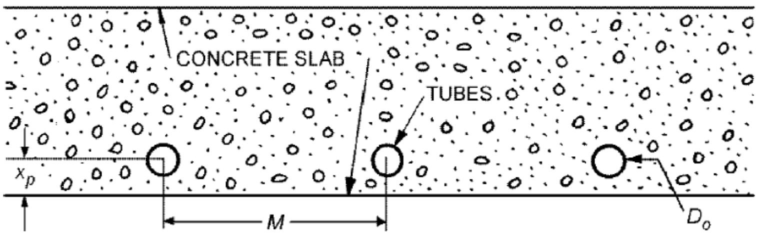

Figure 2-2: Radiant system composed of embedded tubes in concrete (McDowall, 2007)

2.4.2.2 HVAC - Chilled beams

Chilled beams mainly depend on convection for heat transfer (Schultz, 2007). They can save between 10% to 20% of energy consumption per year, depending on the project size (Roth et al., 2007). There are two types of chilled beam systems, which are passive and active (Schultz, 2007).

Passive chilled beams

Passive chilled beam systems comprise of a coil with fins covered by metal sheeting, as shown in Figure 2-3 (Roth et al., 2007). In the cooling system, chilled water with temperatures of 13° C to 17° C passes through the coil, which in turn cools the air and forces it to move down to the ground level (Roth et al., 2007). These systems provide cooling densities of approximately 60 W/m^2 to 70 W/m^2 (Roth et al., 2007).

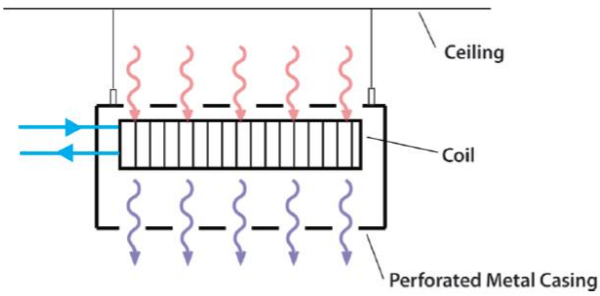

Figure 2-3: Passive Chilled Beam operation diagram (Roth et al., 2007)

Active chilled beams

Active chilled beam systems are more complex than passive chilled beam systems as they are equipped with an air supply that passes through the cooling coil and drops down to the building floor (Roth et al., 2007). See Figure 2-4. They provide cooling densities of approximately 130 W/m^2 to 160 W/m^2 (Roth et al., 2007).

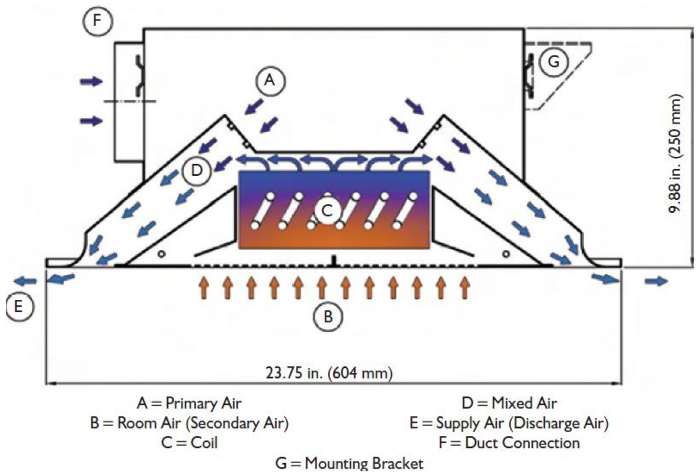

Figure 2-4: Active chilled beam operation diagram (Alexander and O'Rourke, 2008)

Advantages

Special features such as lighting, smoke detectors, speakers, sprinklers and power points can be integrated into the chilled beam (Schultz, 2007). Chilled beam systems provide a better indoor environment, which increases employees' productivity (Henderson, 2003).

Disadvantages

There are several disadvantages of using chilled beam systems, including the following:

- High capital cost (Roth et al., 2007),

- Location constraints exist for passive chilled beam systems as they cannot be installed above high heat load machines because the rising warm air will neutralize the falling cool air (Schultz, 2007),
- Limited heating capacity, with a heating density between 25 W/m^2 and 50 W/m^2 (Schultz, 2007),
- Humidity level must be controlled or surface condensation and mould growth might occur (Dieckmann et al., 2004),
- In the passive chilled beam system, it is very important to check the CO_2 levels in the room to avoid under-ventilation (Alexander and O'Rourke, 2008).

2.4.2.3 HVAC - Underfloor air distribution

The underfloor air distribution (UFAD) system requires the availability of approximately 300 mm of clearance or a minimum of 250 mm over the slab floor for installation (ASHRAE, 2003). This clearance is used for the installation of the airflow pipes located beneath the raised floor (ASHRAE, 2003). The UFAD system consists of high induction swirl diffusers that circulate the air in an upward direction directly to the occupied zone (Hui and Li, 2002). The air then returns by going through the ceiling grilles (Hui and Li, 2002). See Figure 2-5. The air supply delivered by the UFAD system is between 16 and 17° C, which is higher than the air supplied from the traditional HVAC system by approximately 4° C, and this allows it to be more energy efficient (Hui and Li, 2002). In addition, the UFAD system is able to provide high heat loads, generally between 190 to 950 W/m^2 (Hui and Li, 2002).

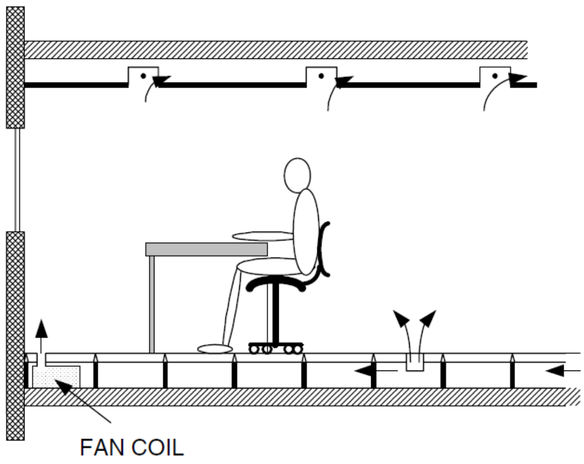

Figure 2-5: UFAD system (McDowall, 2007)

Advantages

The UFAD system enhances indoor air quality by carrying suspended air particles and body odours directly to the upper ceiling grilles, which helps significantly in keeping the occupied zone clean and fresh (Janis and Tao, 2005). The raised access flooring can also be integrated to include many other applications, such as electrical power, telephone and data cables (Hui and Li, 2002). UFAD can improve thermal comfort for individual occupants, improve air movement and ventilation effectiveness, improve occupant satisfaction and thus increase work productivity, and provide energy savings compared to conventional overhead systems (Webster, 2005).

Disadvantages

A number of disadvantages related to using the UFAD system are summarized below:

- High capital cost (Hui and Li, 2002),
- Issues related to the sanitation of the under-floor space, such as the accumulation of dust and dirt (Woods, 2004),
- Condensation and growth of mould on the concrete plenum when the temperature of the air supplied by the system is less than 63° F (Woods, 2004),

- Thermal discomfort (Woods, 2004),
- Draught discomfort (Chao and Wan, 2004),
- Constraints due to the location of the diffusers (Zhang and Yang, 2006).

2.4.2.4 HVAC - Night purge and natural ventilation

A night purge and natural ventilation system can be used in office or commercial buildings, due to the fact that these buildings are unoccupied during the night (Kolokotroni and Aronis, 1999). The system helps in reducing energy consumption by using natural or mechanical ventilation to let in the cool night air, which in turn reduces the inside temperature of the air, the fabric and the building slab (Kolokotroni and Aronis, 1999), as shown in Figure 2-6. The automatic control system of the night ventilation system can be a stand-alone system or part of the building management system (BMS) operations (Martin and Fitzsimmons, 2000).

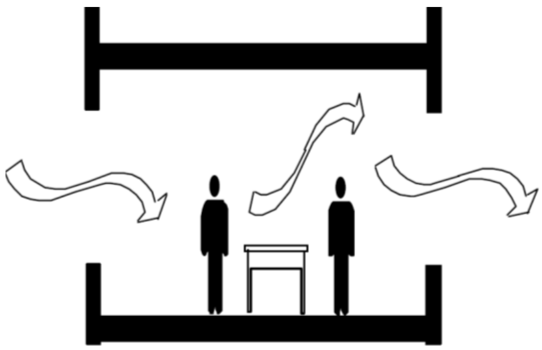

Figure 2-6: Night purge and natural ventilation working scheme (Martin and Fitzsimmons, 2000)

Advantages

The night purge and natural ventilation system assists in reducing peak air temperatures during the day and can reduce the energy consumption of a building by 5% (Kolokotroni and Aronis, 1999). Natural ventilation in general can provide lower operating costs, simpler and more manageable environmental control systems, reduced environmental impact, productivity improvement, and increased robustness, flexibility and adaptability (Martin and Fitzsimmons, 2000).

Disadvantages

The design of a night purge and natural ventilation system requires the involvement of architects, engineers, designers and consultants, which might be sometimes difficult to arrange and control (Conahey et al., 2002). It also involves the use of simulation models that can only be run by specialist personnel to predict the internal temperature and air speed (Conahey et al., 2002). The fact that the night ventilation system allows the building's windows to be open at night, might lead to security issues and unauthorized access (Martin and Fitzsimmons, 2000). Furthermore, automated windows may not work properly, which can cause commissioning and maintenance problems (Torcellini et al., 2004). It is essential for natural ventilation to have an open plan or an air pathway through the hot areas for it to operate well (Martin and Fitzsimmons, 2000). Obstacles, such as high partitions, filing cabinets and furniture will restrict the air flow into the required locations and reduce the effectiveness of the night ventilation system (Martin and Fitzsimmons, 2000).

2.4.2.5 Lighting - Energy efficient light bulbs

Approximately 23% of an office building's energy usage comes from lighting (Yudelson, 2007). There are many types of lamps used at present but not all are energy efficient. Green buildings require energy efficient products to be installed in them, as this contributes to the overall energy efficiency of the green building. The efficiency of light lamps can be expressed as lumens per watt (lpw) (Janis and Tao, 2005). In theory, a white light lamp can achieve an efficiency of 200 lpw (Janis and Tao, 2005). This section will provide an overview of the available energy efficient light lamps and their advantages.

Types of energy efficient light bulbs

The main types of energy efficient light bulbs are: fluorescent lamps, high intensity discharge (HID) lamps and light emitting diode (LED) lamps. Each comes in different shapes, sizes and lpw ratios.

Fluorescent lamps consist of a tube filled with mercury vapour and two electrodes positioned at the ends (Janis and Tao, 2005). Ultraviolet energy is produced as soon as electric current is introduced between the two electrodes, and this energy is then converted into visible energy by a phosphor coating inside the lamp (Janis and Tao, 2005). Generally, fluorescent lamps have a tubular shape and are made in different lengths and diameters (Janis and Tao, 2005). The energy efficiency of these lamps depends on their type and rating, and the nominal efficiency varies between 50 and 104 lpw (Janis and Tao, 2005). The life of a fluorescent lamp depends on its type and can be anywhere from 5000 hours up to 30,000 hours, which indicates an excellent life rating (Janis and Tao, 2005). The types of commercial fluorescent lamps are: instant start lamps, rapid start lamps, compact lamps and specialty lamps (Janis and Tao, 2005).

HID lamps are made of high pressure arc tubes filled with a metallic gas like mercury, argon or sodium (Janis and Tao, 2005). There are many types of HID lamps, and the major classes are: mercury vapour lamps, metal halide lamps, high pressure sodium lamps, low pressure sodium lamps, induction lamps and sulphur lamps (Stein and Reynolds, 2000). The average lamp life cycle and energy efficiency differ among the major classes (Stein and Reynolds, 2000). For instance, mercury vapour lamps have an average life span of 24,000 hours or more and an energy efficiency rate that varies between 39 and 55 lpw (Stein and Reynolds, 2000). On the other hand, low pressure sodium lamps have a nominal life span of 18,000 hours and an energy efficiency rate that exceeds 150 lpw (Stein and Reynolds, 2000).

Multiple layers of semiconductor material are used in the manufacture of LED lamps, in which the LED is a semiconductor p-n junction lamp (Janis and Tao, 2005). Light is generated in the thin layer of the LED lamps when the diode is forward-biased (Janis and Tao, 2005). The efficiency of these lamps varies and depends on the colour. For instance, white LED lamps can achieve an energy efficiency rate up to 20 lpw, while yellow LED lamps can achieve an energy efficiency rate up to 100 lpw (Janis and Tao, 2005).

Advantages

Fluorescent, HID and LED light bulbs generally have the same advantages. For example, they all have a long lifecycle and they are also energy efficient (Janis and Tao, 2005). Energy efficient light bulbs can be used in open offices, private offices, executive offices, board and conference rooms, classrooms, corridors, and high bay spaces (ASHRAE, 2006).

Disadvantages

Fluorescent lamps are sensitive to temperature due to the temperature sensitivity of mercury vapour (Janis and Tao, 2005). These lamps are designed to be most efficient at an ambient temperature of 25 °C (Janis and Tao, 2005). If the lamp is exposed to ambient temperatures near or below zero it may fail to operate (Janis and Tao, 2005). Fluorescent lamps emit a certain amount of ultraviolet radiation that can affect people with extreme sensitivity to this radiation (HC, 2009). Some people also suffer from headaches and depression when exposed to fluorescent lamps (HC, 2009). HID lamps generally have a long start-up and restart time, as it takes the lamp from 1 to 5 minutes to start up and from 1 to 15 min to restart (Janis and Tao, 2005). This makes HID lamps unsuitable in places where frequent on and off operations are required (Janis and Tao, 2005).

2.4.2.6 Lighting - Motion sensors

Motion sensors or occupancy sensors are used to turn lights on when occupants are in a room or turn them off after they leave the room (Stein and Reynolds, 2000). See Figure 2-7. There are three types of motion sensors: passive infrared, ultrasonic and a hybrid of infrared and ultrasonic technology (Stein and Reynolds, 2000). The infrared sensor reacts to the movement of a heat source within its coverage range and will not react to a stationary heat source (Stein and Reynolds, 2000). An ultrasonic sensor emits waves that are in the range of 25 to 40 kHz, which cannot be heard by humans (Stein and Reynolds, 2000). These waves fill a space by reflecting off hard surfaces and the sensor detects any movement that disturbs these waves (Stein and Reynolds, 2000). The hybrid sensor turns on the lights only when both the infrared and ultrasonic sensors react to a movement and turns off the lights only when both sensors do not sense movement. If one sensor senses movement, the lights will stay on (Stein and Reynolds, 2000).

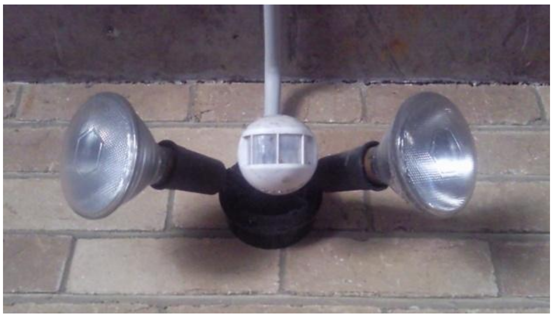

Figure 2-7: Motion sensor (picture by Ibrahim Mosly)

Advantages

Motion sensors can generally lower energy usage by minimising the use of electricity (ASHRAE, 2006), which in turn helps in reducing greenhouse gas emissions and the impact on the environment. They need virtually no maintenance and are low to moderate in cost for most areas (ASHRAE, 2006).

Disadvantages

The infrared sensor has the disadvantage of detecting slow and small movements (Stein and Reynolds, 2000). In addition, if the moving object is behind an obstacle, such as a piece of furniture then it will not be detected by the sensor as the furniture will obstruct the infrared beams (Stein and Reynolds, 2000). On the other hand, ultrasonic sensors can detect the smallest movement in space, which means that they may react to insignificant movements, such as the movement of curtains due to air-conditioning flow (Stein and Reynolds, 2000).

2.4.3 Renewable energy technologies chosen for this research

Renewable energy technologies can be classified into two types according to their supply sources: onsite and offsite (Torcellini et al., 2006). Onsite supply options refer to technologies that use energy sources available onsite and offsite options refer to technologies that use energy generated at another location (Torcellini et al., 2006). Solar technologies such as photovoltaic panels and solar thermal heating are the most applicable onsite technologies (Torcellini et al., 2006). Other technologies, such as wind, are also applicable but have limited applications (Torcellini et al., 2006). Therefore, solar and wind were selected as the two groups for renewable energy technologies because they can be feasibly implemented in office buildings without being concerned with the topography and location of building. The renewable solar energy technologies investigated in this research include photovoltaic panels and solar thermal heating, and the wind energy technology is wind turbines.

2.4.3.1 Solar - Photovoltaic panels

Solar photovoltaic (PV) cells are used to generate electricity from sunlight (Turkenburg, 2000). See Figure 2-8. PVs are a clean, green and carbon-free source of electrical energy (Hall, 2006). The size of the PV system depends on the amount of energy required to be produced (Hall, 2006). In order to receive the most sunlight, it is best to face the PV cells toward the sun at angles of between 20 and 50 degrees (Hall, 2006). PVs can be used as off-grid or grid-connected systems (Turkenburg, 2000). Off-grid PV systems are equipped with a battery to store the energy, which can be used when sunlight is not sufficient (Turkenburg, 2000). Commonly, lead acid batteries are used to storage energy from PV cells (Turkenburg, 2000). Grid-connected PV systems are more convenient than off-grid PV systems, as they use the local grid network as a massive battery (Hall, 2006). The electricity produced from PV cells is direct current (DC) electricity, while the electricity used inside homes and offices is classified as alternating current (AC) electricity (Hall, 2006). In DC electricity the electrons flow in only one direction around the circuit but in AC electricity the electrons flow back and forth through the circuit at higher voltages (Hall, 2006). To resolve this issue, a device called an inverter is used to turn low voltage DC current into high voltage AC current (Hall, 2006).

Figure 2-8: Photovoltaic panels (picture by Ibrahim Mosly)

Advantages

The PV system has many advantages, such as producing electricity in a clean and green way (Hall, 2006). It also plays a significant role in increasing the value of a building by making it look more attractive and aesthetically pleasing (Kaan and Reijenga, 2004). Off-grid PV systems can be used to power many types of equipment, such as lights, radios, telephones, TVs, refrigerators, offshore navigation buoys, lighthouses, warning signals and many more (Mumtaz and Amaratuga, 2006). Grid-connected PV systems have a unique advantage over off-grid PV systems (Mumtaz and Amaratuga, 2006). When the amount of electricity generated by the grid-connected PV system is higher than the amount of electricity consumed by the building, the extra electricity is then supplied to the grid and the owner receives credit from his supplier (Mumtaz and Amaratuga, 2006).

Disadvantages

Like any other technology, PVs have several disadvantages, some of which are summarized below:

- The PV technology is among the most costly renewable energy technologies available (Knight, 2005),

- Some components of the PV system have shorter lifetimes than the PV module itself, which means that they have to be replaced more often, and this will delay the payback period. For instance, the power conditioning unit has a typical lifetime of less than 5 years, while the PV unit can serve up to 25 years (Mumtaz and Amaratuga, 2006),
- Weather conditions are variable, and dust and other small particles can accumulate over the PV unit and affect its performance (Diarra and Akuffo, 2002),
- In case of system failure for any reason, it may be difficult to find qualified professional personnel to repair the failure in some countries (Diarra and Akuffo, 2002),
- Physical degradation may occur and affect the PV module's performance due to the outdoor exposure (Realini, 2003),
- Appearance view can be an issue with PV systems, especially if they are installed near a natural beauty area or on a historical building (Tsoutsos et al., 2005).

2.4.3.2 Solar - Solar thermal systems

Like PV systems, solar thermal (ST) systems work by using sunlight but the difference is that ST transfers the sunlight into heat rather than electricity (see Figure 2-9). The temperature of heat produced can reach up to 100° C (Turkenburg, 2000). The solar thermal hot water (STHW) system comprises three main components: a solar collector panel, a storage tank and a circulation system (Turkenburg, 2000). This system varies in size and price according the demand for heat required by the building occupants and the climate conditions of the building's location (Turkenburg, 2000).There are three types of collectors: unglazed plastic, flat plate and evacuated tube (Hall, 2006). Unglazed plastic collectors are used in applications that require low heat production, such as swimming pools, while flat plate collectors are highly insulated to reduce heat loss and works by increasing the solar gain (Hall, 2006). Evacuated tubes can work at high temperatures and are more expensive than other collectors (Hall, 2006). The storage tank is usually an insulated container made of steel or concrete (Hall, 2006). In areas known for serious frost, pumps are usually added to the STHW system for circulation purposes and sometimes antifreeze is added to the collector fluid (Turkenburg, 2000). Areas with warmer climates generally use natural circulation systems (Turkenburg, 2000). STHW systems are usually made of aluminium, copper, steel, glass and insulation materials that can be simply disassembled for recycling (Turkenburg, 2000).

Figure 2-9: Solar thermal system (picture by Ibrahim Mosly)

Advantages

ST systems are one of the efficient types of solar energy technology available on the market at present (NSES, 2007). They depend on harvesting sunlight for their operation, which is a renewable source of energy (NSES, 2007). ST systems also have a negligible impact on the environment and produce an insignificant amount of greenhouse gas emissions (NSES, 2007). In some countries, tax credit or rebate schemes are offered to those who install a ST system and that helps in reducing initial costs (NSES, 2007).

Disadvantages

Several disadvantages of the ST system are as follows:

- Heat is usually required when the sunlight is very low or not present (Turkenburg, 2000),
- Poor performance, such as the loss of heat from the storage unit (Philibert, 2006),
- The installation of a ST system requires the availability of skilled and knowledgeable personnel that are capable of installing the system in a proper working condition (Philibert, 2006),
- High capital cost compared with conventional electrical systems (Philibert, 2006),
- Legal constraints in some countries, including permits from the local council before installation (Philibert, 2006).
- Like the PV system, the ST system can also have a negative visual impact on its surroundings (Tsoutsos et al., 2005).

2.4.3.3 Wind - Wind turbines

The use of wind power has increased greatly in the past years, from an estimated capacity of 2.3 GW in 1991 to an approximate capacity of 40 GW in 2003 (Morthorst, 2006). Wind power can be used for water pumping or electricity production in both grid-connected and stand-alone systems (Morthorst, 2006). Wind turbines operate by converting kinetic energy from the wind into mechanical energy using rotors (Hau, 2006). The mechanical energy is converted into electrical energy by an electrical generator (Hau, 2006). See Figure 2-10. Wind turbines are categorized into three main sizes: small, medium and large (Gipe, 2004). The wind turbine size mainly depends on the rotor diameter (Gipe, 2004). The rotor sizes of small wind turbines range from less than 1.25 meters to 8.8 meters in diameter, those of medium wind turbines range from 10 meters to 60 meters in diameter, and those of large wind turbines can reach up to 100 meters in diameter (Gipe, 2004). For capturing wind energy, small wind turbines are less effective than medium wind turbines (Gipe, 2004). Small wind turbines perform best in low wind conditions, usually at typical wind speeds of 4 to 5 m/s, while higher wind speeds will significantly decrease their performance (Gipe, 2004). They rarely capture more than 30% of wind energy (Gipe, 2004). There are two types of wind turbines: vertical axis and horizontal axis (Gipe, 2004). Vertical axis wind turbines (VAWTs) can work under different wind circumstances, as they accept wind blowing from all directions (Gipe, 2004). On the other hand, the traditional horizontal axis wind turbines (HAWTs) only work with wind blowing from one direction and if there is a change in the wind direction the device's direction has to be changed (Gipe, 2004).

Figure 2-10: Wind turbines (picture by Ibrahim Mosly)

Advantages

Wind turbines are a source of clean and renewable energy that can be used in houses, farms, schools, facilities and rural locations (Weaver and Forsyth, 2006). They also reduce the demand on traditional electricity sources (Weaver and Forsyth, 2006). In addition, harmful emissions are not produced by wind turbines (AWEA, 2001). Wind energy is currently used for passive ventilation and power generation (Dutton et al., 2005). Passive ventilation uses the wind to extract the air from the building without forced ventilation (Dutton et al., 2005). Wind turbines help in decreasing or eliminating electricity invoices (AWEE, 2009), and tend to enhance the security of the electrical supply as well as provide insurance against increasing electricity prices (AWEE, 2009).

Disadvantages

Aesthetic design can be a problem with wind turbines, as not all designs look good or consistent with a building (Gipe, 2004). Noise is also a source of risk, as all wind turbines produce noise as they operate, which can be a concern to the owners and their neighbours (Gipe, 2004). The source of the noise comes from the blades, transmission gear and generator (Gipe, 2004). Wind turbines can also cause vibration in the building, which might bring discomfort to the building occupants or even fatigue damage to the structure of the building in the long term (Dutton et al., 2005). The risk of birds colliding with wind turbines and dying also exists, as birds are known to collide with any structure elevated above the surface (Gipe, 2004). Wind turbines are expensive and have a high initial cost, and small wind turbines are more expansive than medium and large turbines (Gipe, 2004). The maintenance of wind turbines can be very costly due to the high cost of hiring professionals (Gipe, 2004). Installing a wind turbine on a building can lead to an increase in the building's insurance premium, due to the largely unknown risks (Dutton et al., 2005). Design risks are also possible when identifying the essential data for the design of a wind turbine, such as the wind conditions surrounding the building, the wind turbines structural integrity with the building and specific design requirements for metropolitan wind turbines (Bussel and Mertens, 2005). One of the main disadvantages of wind turbines is lower performance than expected (Dutton et al., 2005). Wind blocking can lower the turbine's performance, as new buildings and trees can reduce the wind (Dutton et al., 2005).

2.5 Risks of Energy Efficient & Renewable Technologies

In the long process of operation and development of new technologies, a series of technical, economic and institutional barriers must be overcome (Elliott, 2003). In the case of sustainable energy technologies, these barriers and constraints are particularly clear (Elliott, 2003). The role that new energy technologies can play in sustaining the shift towards a sustainable energy future and the pace of this shift may be affected by these barriers and constraints (Elliott, 2003).

Risk identification is the first step in the risk management process. It aims to produce a broad list of risk triggers and events that may have an impact on the achievement of objectives initially identified in the context (AS/NZS, 2004). The identification should include risks that can be or cannot be controlled by the organization (AS/NZS, 2004).

Risks associated with EERTs have been investigated by a large number of authors, who refer to the risks as barriers, impediments, challenges, issues, and limitations. For example, Sovacool explored ways to promote energy efficiency and renewable technologies by managing a number of identified impediments to the implementation of EERTs (Sovacool, 2009a). He conducted 181 semi-structured interviews and developed a list of 30 policy mechanisms (Sovacool, 2009a).

Other authors have investigated the barriers of renewable energy technologies (Painuly, 2001). On the basis of a literature survey, site visits, and interactions with stakeholders, Painuly (2001) identified 41 barriers to prevent the penetration of renewable energy technologies.

On the other hand, some authors have investigated the risks of energy efficient technologies. For example, Reddy and Shrestha (1998) explored the barriers to implementation of energy efficient technologies and using questionnaires and interviews, they identified seven main implementation barriers. A report by the National Round Table on the Environment and the Economy (NRTEE) and the Sustainable Development Technology Canada (SDTC) discussed the barriers to investment in energy efficient technologies in the commercial building sector in Canada and highlighted 30 barriers to the adoption of energy efficient technologies (NRTEE and SDTC, 2009).

Other authors have focused only on the risks of specific EERTs. For instance, Zhang and Yang (2006) explored the significant influencing factors or potential issues of UFAD technology. Questionnaires and interviews were used for data collection and the final outcome was the identification of 44 significant factors influencing the implementation of UFAD in Australia (Zhang and Yang, 2006).

2.5.1 Risk categorization

In a study of the barriers to renewable energy penetration, Painuly (2001) categorized these barriers into 7 categories: 1. market failure/imperfection, 2. market distortions, 3. economic and financial, 4. institutional, 5. technical, 6. social and cultural, and 7. other. Another report categorised the risks and barriers to the adoption of energy efficient technology in the commercial building sector into: 1. risk management, 2. information gaps, 3. value chain and principal-agent relationship, 4. first mover disadvantage, 5.

market price signals, 6. institutional an regularity (NRTEE and SDTC, 2009). Greden et al. (2007) classified the uncertainties or risks of innovative technologies that are applicable to design as follows: 1. market uncertainty, 2. climate uncertainty, 3. regularity uncertainty, 4. technological uncertainty, and 5. uncertainty in future use of real estate and/or land. In a study to assess the best approach to the promotion of renewable energy and energy efficiency in the United States, impediments to energy efficiency and renewable power were categorized under four categories (Sovacool, 2009a). These categories are: 1. Financial and market impediments, 2. Political and regularity obstacles, 3. Cultural and behavioural barriers, 4. Aesthetic and environmental challenges.

Since this research focuses on the implementation of EERTs in green office buildings, the risks are divided into four major categories:

- Financial and market risks,
- Technical risks,
- Political and cultural risks,
- Environmental, health and safety risks.

Based on the work of the above authors, the selection of the four categories was made in order to sufficiently cover all types of risks identified. These categories are adequate for the easy categorization of previously-identified EERT risks.

2.5.2 Risks of EERTs

To investigate the risks associated with EERTs, a total of 66 references including books, journal articles, conference papers, reports and official internet websites were examined. The outcome of the comprehensive literature review was the identification of 30 risks, which are explored in the following sections:

2.5.2.1 Financial and market risks:

1. **Emergence of new and superior technology**

Technologies are always subjected to improvement and innovation, but in the case of EERTs the pace at which a new and superior technology is introduced to the market might affect consumer behaviour in buying these types of technologies in the first place. This is due to many reasons, including the original technology becoming obsolete, missed efficiency opportunities, or missed saving opportunities. When engineers and specialized workers decide to invest in using new technologies competencies in existing technologies will become obsolete (Tsoutsos and Stamboulis, 2005). A newly-introduced technology can compete with its original version (Greden et al., 2007). At the same time, it can render a given renewable energy investment less attractive (Hassett and Borgerson, 2009).

2. **Hidden costs**

Hidden costs can occur in any project, including those involving the implementation of EERTs. After the acquisition of an energy efficient product or service, unexpected costs will often occur (Meyers, 1998). These unexpected costs may include additional costs of operation and maintenance, staff costs of monitoring or servicing transactions, or quality of installation (Meyers, 1998). Some authors argue that a renewable energy technology may be cost-effective on average but its hidden costs, including operation and management, inconvenience, and collecting and analysing information, may be high (Reddy and Painuly, 2004).

3. Lack of access to funds

In the present research, lack of access to funds refers to the inability or difficulty of the EERTs owner to obtain funds for the purpose of purchasing the technology. This is an issue with renewable energy technologies (Mirza et al., 2009; Owen, 2006; Painuly, 2001; Reddy and Painuly, 2004; Turkenburg, 2000). For instance, in the case of the United States, homeowners face a lack of capital or access to it to acquire renewable energy technologies (Sovacool, 2009a). Lack of access to funds is also an issue with energy efficient technologies because, in many developing and transitioning countries capital for investment is scarce, especially if foreign exchange is required (Meyers, 1998).

4. Lack of access to information about technology

EERTs may also be subjected to the risk of lack of access to information about the technology (Martinot, 1998; Singh et al., 2006; Sovacool, 2009a). Several authors have identified this risk for renewable energy technologies in their work (Mirza et al., 2009; Painuly, 2001; Reddy and Painuly, 2004). As with energy efficient technologies, this risk has been identified by many authors (Brown, 2001; Meyers, 1998; NRTEE and SDTC, 2009). Information related to these technologies is often asserted to be inadequate and this discourages the consumer from proceeding with the investment (Reddy and Shrestha, 1998).

Lack of access to information is a risk for UFAD technology (Bauman and Webster, 2001; Hui and Li, 2002; Zhang and Yang, 2006). Although an increased number of publications on UFAD have become available in recent years, as yet there is no complete understanding of some fundamental fluid mechanics and thermal problems and no standardized design methods exist (Webster, 2005). Photovoltaic panels in Mali have encountered the risk of lack of access to information about the technology, and consumers there lack education on the limits of photovoltaic panels (Diarra and Akuffo, 2002). With wind turbines, there is a lack of public awareness of these technologies and information on performance standards, testing, and ratings is lacking (Weaver and Forsyth, 2006).

5. **Lack of access to spare parts**

Not being able to access spare parts for EERTs due to unavailability or low stock is a potential risk. In the case of renewable technologies or equipment that is generally imported, replacement parts are not necessarily available when required, especially in remote areas (Mirza et al., 2009). A study of barriers to EERTs in Thailand found that lack of access to necessary spare parts is one of the top five barriers to implementation of these technologies (Adhikari et al., 2008).

6. **Lack of access to the technology**

Lack of access to the technology itself is a potential risk for several EERTs (Mirza et al., 2009; Reddy and Shrestha, 1998; Singh et al., 2006; Weaver and Forsyth, 2006). For example, in the case of renewable energy technologies, they may not be freely available on the market or there may be restrictive policies or taxes on the technology, or the importation of the product is barred (Painuly, 2001). With energy efficient technologies, the decisions and practices of manufacturers and/or suppliers can result in limited availability of products or services (Meyers, 1998). In rural areas and towns the availability of energy efficient technologies is lower than in large cities and prices are often higher (Meyers, 1998).

7. Lack of skilled personnel

Lack of availability of skilled personnel has been identified as a risk for EERTs (Adhikari et al., 2008; Cooke et al., 2007; Martinot, 1998; Parthan et al., 2009). Several authors have identified this risk for a variety of energy efficient technologies (Alajmi and El-Amer, 2010; Bauman and Webster, 2001; Dieckmann et al., 2004; NRTEE and SDTC, 2009; Pinkse and Dommisse, 2009; Roth et al., 2007; Webster, 2005; Yudelson, 2008; Zhang and Yang, 2006). The lack of availability of skilled personnel with respect to energy efficient technologies may be apparent in government agencies and financial institutions (Meyers, 1998). Governmental agencies often do not have the skilled personnel to design and implement energy efficiency programs and financial institution do not have the skilled personnel to evaluate investments related to energy efficiency or may be unfamiliar with their financing schemes (Meyers, 1998). This indicates the need for skilled personnel in all fields, not only the construction industry. A number of authors pinpointed the lack of availability of skilled personnel for renewable energy technologies (Diarra and Akuffo, 2002; Mirza et al., 2009; Painuly, 2001; Philibert, 2006). For example, the installation of such technologies requires the involvement of professional personal, as unqualified people can damage the photovoltaic panels during installation (Hayter et al., 2002).

8. Uncertain payback period

An uncertain payback period is a risk for EERTs (Cooke et al., 2007), and several authors have identified the risk of uncertain payback period for renewable technologies (Reddy and Painuly, 2004; Sovacool, 2009b). The risk of having a high payback period is correlated with having a low rate of return, inadequate incentives and high tax on profits (Painuly, 2001). The risk of uncertain payback period is also significant in energy efficient technologies (Meyers, 1998). For instance, first movers can be disadvantaged by this risk, especially with variations in payback ratios that represent the actual versus what is required (NRTEE and SDTC, 2009).

2.5.2.2 Technical risks

9. Draught & thermal discomfort

The risk of draught and thermal discomfort is related to technologies listed under the HVAC category (Hui and Li, 2002; Melikov et al., 2007; Webster, 2005; Woods, 2004; Zhang and Yang, 2006). For instance, some radiant cooling systems installed in California showed problems in providing thermal comfort to occupants (Feustel and Stetiu, 1995). Active chilled beams can cause drafts in cold climates (Schultz, 2007). For example, an experiment on an underfloor air distribution system showed that a high draught rate was created within a small region of the outlet (Chao and Wan, 2004).

10. Low product and performance reliability

Performance reliability of the technology is very important for its success in the market. EERTs are subject to the risk of low product and performance reliability (Cooke et al., 2007; Singh et al., 2006). A number of authors have identified this risk for renewable energy technologies (Diarra and Akuffo, 2002; Dutton et al., 2005; Evans et al., 2009; Hassett and Borgerson, 2009; Mirza et al., 2009; Painuly, 2001; Reddy and Painuly, 2004; Tsoutsos and Stamboulis, 2005; Weaver and Forsyth, 2006). Performance uncertainties may apply to all technologies, but especially to those which are new and unfamiliar (Meyers, 1998). In developing countries, the performance of some technologies may deteriorate more rapidly due to prevailing conditions such as fluctuation of electricity voltage (Meyers, 1998). The occurrence of this risk is also a potential in energy efficient technologies (Feustel and Stetiu, 1995; Greden et al., 2007; Houri and Khoury, 2010; Lovorn, 2009; NRTEE and SDTC, 2009; Stein and Reynolds, 2000; Torcellini et al., 2004; Webster, 2005; Woods, 2004; Yuen et al., 2010).

11. Noise and building vibration

A number of authors identified noise and building vibration as a risk for wind turbines (Abbasi and Abbasi, 2000; Grant et al., 2008). Noise refers to the local pollution to the environment by the technology such as noise and visual impact in the case of wind energy (Painuly, 2001). Noise is a source of risk for wind turbines (Gipe, 2004; OECD/IEA, 1998; Turkenburg, 2000). Vibration may cause long term fatigue damage to the building structure and nuisance to the building occupants (Dutton et al., 2005).

12. Operational failure

The risk of operation failure refers to the total failure of the technology to operate and perform as it should. Several authors identified operation failure as a risk for EERTs (Abbasi and Abbasi, 2000; Dutton et al., 2005; Evans et al., 2009; Hassett and Borgerson, 2009; Janis and Tao, 2005; Tsoutsos and Stamboulis, 2005).

13. Physical degradation

Physical degradation refers to the downgrade or erosion of the technology which in turn affects its performance. Physical degradation may affect the performance of photovoltaic panels due to their outdoor exposure (Realini, 2003). The physical degradation may be in the form of colour change, oxidation, delamination and cell cracks (Realini, 2003). Some parts of the photovoltaic panels, such as the terminals may become oxidized and cause defects such as higher electrical resistance (Realini, 2003).

14. Presence of system constraints

The risk of system constraints refers to capacity limitations, integration problems and lack of skill with renewable energy technologies (Painuly, 2001). Many authors have identified this risk for energy efficient technologies (Alexander and O'Rourke, 2008; Feustel and Stetiu, 1995; Henderson, 2003; Houri and Khoury, 2010; Martin and Fitzsimmons, 2000; Roth et al., 2007; Schultz, 2007; Yuen et al., 2010; Zhang and Yang, 2006). In the present research the risk of system constraints will mainly refer to capacity limitation and integration problems.

15. Slow response rate to temperature changes

The risk of slow response rate to temperature changes is specifically related to the HVAC category. For instance, radiant systems are not able to respond quickly to transient conditions compared to other systems with forced air capability (Yudelson, 2008).

2.5.2.3 Political and cultural risks

16. Low consumer demand and acceptance

The risk of low consumer demand and acceptance is applicable to energy efficient technologies (Houri and Khoury, 2010; NRTEE and SDTC, 2009; Pinkse and Dommisse, 2009; Reddy and Shrestha, 1998; Zhang and Yang, 2006), as well as renewable energy technologies (Painuly, 2001; Reddy and Painuly, 2004; Tsoutsos and Stamboulis, 2005; Turkenburg, 2000). This may be in the form of reluctance to implement or lack of interest in EERTs.

17. Misplaced incentives

The risk of misplaced incentives can affect energy efficient technologies (Meyers, 1998; NRTEE and SDTC, 2009), and renewable energy technologies (Owen, 2006; Philibert, 2006; Reddy and Painuly, 2004). The risk of misplaced incentives sometime referred to as split incentives, can be seen in two forms. The first is when builders make energy choices for homeowners (Sovacool, 2009a). Here the builder has the authority to act on behalf of the owner but this does not mean that they reflect the best interests of the owner (Brown, 2001). They seek to minimize costs and select the energy technologies that the owners must use (Brown, 2001). However, the owner's best interests would be to select technologies based on lifecycle costs (Brown, 2001). The second form is when landlords make energy choices for tenants (Sovacool, 2009a). In this case, the tenants will pay the bills and consequently the landlord will have no incentive to make energy efficient investments (Parthan et al., 2009).

18. Uncertain availability of incentives

The risk of uncertain availability of incentives includes variable and inconsistent incentives or subsidies offered by the government. A number of authors have pinpointed this risk for EERTs (Adhikari et al., 2008; Martinot, 1998; Sovacool, 2009a). Some researchers have identified this risk for energy efficient technologies (Greden et al., 2007; Meyers, 1998; NRTEE and SDTC, 2009) and others for renewable energy technologies (Reddy and Painuly, 2004; Weaver and Forsyth, 2006).

19. Uncertain government policies

Similar to the uncertain availability of incentives, the risk of uncertain governmental polices includes variable and inconsistent policies. Several authors see this risk as being applicable to EERTs (Parthan et al., 2009; Singh et al., 2006). A number have identified it for energy efficient technologies (Brown, 2001; Greden et al., 2007; NRTEE and SDTC, 2009), and others for renewable energy technologies (Komendantova et al., 2009; Mirza et al., 2009; Painuly, 2001; Reddy and Painuly, 2004; Tsoutsos and Stamboulis, 2005; Turkenburg, 2000; Weaver and Forsyth, 2006). This risk includes government bureaucracy (Adhikari et al., 2008; Sovacool, 2009a). For instance, delays and extra costs can occur during the process of applying for a permit from the local council before installing a solar thermal system (Philibert, 2006).

2.5.2.4 Environmental, health and safety risks

20. Aesthetically unpleasing

The aesthetically unpleasing risk applies generally to renewable energy technologies (Abbasi and Abbasi, 2000; Evans et al., 2009; Gipe, 2004; Grant et al., 2008; Kalogirou, 2009; OECD/IEA, 1998; Tsoutsos et al., 2005; Tsoutsos and Stamboulis, 2005; Turkenburg, 2000) but it also applies to some energy efficient technologies like chilled beams (Roth et al., 2007). The risk is related to the visual looks of these EERTs when implemented (Sovacool, 2009a).

21. Bird collision

The risk of bird collision is related specifically to wind turbines (Abbasi and Abbasi, 2000; Evans et al., 2009; OECD/IEA, 1998; Turkenburg, 2000). Birds are known to collide with any structure elevated above the ground surface, making wind turbines a hazard for them (Gipe, 2004).

22. CO_2 suffocation

The risk of CO_2 suffocation is related to those HVAC technologies that do not provide ventilation. For example, checking the CO_2 levels in a room is very important to avoid under-ventilation (Alexander and O'Rourke, 2008).

23. Dangerous emissions from unit production

The risk of dangerous emissions from unit production is relevant to solar technologies (OECD/IEA, 1998; Tsoutsos et al., 2005; Turkenburg, 2000). Indirect pollution occurs during the manufacture of the collectors and storage devices of solar systems (Abbasi and Abbasi, 2000).

24. Fire risk

Fire risk is related to the solar technologies considered in this research. In solar thermal systems, fire and gas releases from vaporized coolant can occur if accidental leakage happens in coolant systems, thus affecting public health and safety (Tsoutsos et al., 2005).

25. Future change in regional climate and weather fluctuation

Global warming, climate change and future ambient climate all represent a form of climate uncertainty for those systems with performance that depends on climate, such as energy efficient technologies (Greden et al., 2007), and renewable energy technologies (Hassett and Borgerson, 2009; Philibert, 2006). For instance, snow accumulation on photovoltaic panels can decrease system performance (Hayter et al., 2002). High temperatures can also affect the performance of photovoltaic panels, as for every degree increase in temperature beyond the reference temperature indicated by the manufacturer, the power of the photovoltaic panels decreases by 0.5% (Diarra and Akuffo, 2002).

26. Glare risk from collector sunlight reflection

The risk of glare is related to solar technologies (Abbasi and Abbasi, 2000). Glare can be defined as 'the temporary loss of vision or reduction in the ability to see the details of the human eye as a result of a surface whose luminance at a given point in the direction of the observation exceeds the luminance that can be perceived by the human eye' (Chiabrando et al., 2009). Glare can occur from the reflection of the sunlight from the surface of photovoltaic panels (Chiabrando et al., 2009). This can also happen with solar thermal systems.

27. Headaches and skin rash

The risk of headaches and skin rash is specifically related to energy efficient light bulbs. For instance, some people suffer from headaches when exposed to fluorescent lamps, which may be triggered by the flickering or low intensity of these light bulbs (BBC, 2008b). Furthermore, experts report that people with certain skin conditions such as photosensitivity can have worse skin rashes from use of fluorescent bulbs (BBC, 2008a).

28. Leakage of hazardous material

The risk of leakage of hazardous material to the environment or occupancy space may apply to some EERTs, such as radiant systems (McDowall, 2007). For example, fluorescent and HID light bulbs contain mercury, which is a dangerous substance. In the case of light bulb breakage or disposal, mercury can be released and ingested or inhaled through the lungs and into the bloodstream (Friesen, 2008). This risk can also occur with solar thermal systems (OECD/IEA, 1998), as coolant liquids and anti-freeze or rust inhibitors are required to be changed every 2 to 3 years of operation (Tsoutsos et al., 2005). The change process might cause accidental spills or leaks of these toxic fluids (Tsoutsos et al., 2005).

29. Surface condensation and mould growth

The risk of surface condensation and mould growth is related to HVAC technologies (Alajmi and El-Amer, 2010; Barnard and Jaunzens, 2001; Dieckmann et al., 2004; Feustel and Stetiu, 1995; Henderson, 2003; Webster, 2005; Woods, 2004; Yudelson, 2008; Zhang and Yang, 2006). This includes the accumulation of dust, dirt, and mould growth on surfaces of the occupied zone. Air pollution can be a hurdle for using natural ventilation, especially when the outside air is very polluted and unhealthy to breathe (Fordham, 2000). In addition to man-made pollution, natural pollution such as dust, storms, and smoke can also affect human life (Fordham, 2000).

30. Unauthorized building entrance

The risk of unauthorised building entrance is specific for night purge and natural ventilation (Conahey et al., 2002; Kubota et al., 2009; Martin and Fitzsimmons, 2000). For example, a room located on the ground floor or an easily accessible position may require a more sophisticated burglary protection system compared to other higher floor rooms (Roetzel et al., 2010).

Table 2-2 presents all references used in the literature review process and Table 2-3 summarises all risks, the technologies affected by risks, and references.

Table 2-2: References used to identify risks of EERTs

No.	Reference	No.	Reference	No.	Reference
1	(Abbasi and Abbasi, 2000)	23	(Greden et al., 2007)	45	(Philibert, 2006)
2	(Adhikari et al., 2008)	24	(Hassett and Borgerson, 2009)	46	(Pinkse and Dommisse, 2009)
3	(Alajmi and El-Amer, 2010)	25	(Hayter et al., 2002)	47	(Realini, 2003)
4	(Alexander and O'Rourke, 2008)	26	(Henderson, 2003)	48	(Reddy and Painuly, 2004)
5	(Barnard and Jaunzens, 2001)	27	(Houri and Khoury, 2010)	49	(Reddy and Shrestha, 1998)
6	(Bauman and Webster, 2001)	28	(Hui and Li, 2002)	50	(Roetzel et al., 2010)
7	(BBC, 2008a)	29	(Janis and Tao, 2005)	51	(Roth et al., 2007)
8	(BBC, 2008b)	30	(Kalogirou, 2009)	52	(Schultz, 2007)
9	(Brown, 2001)	31	(Komendantova et al., 2009)	53	(Singh et al., 2006)
10	(Chao and Wan, 2004)	32	(Kubota et al., 2009)	54	(Sovacool, 2009a)
11	(Chiabrando et al., 2009)	33	(Lovorn, 2009)	55	(Sovacool, 2009b)
12	(Conahey et al., 2002)	34	(Martin and Fitzsimmons, 2000)	56	(Stein and Reynolds, 2000)
13	(Cooke et al., 2007)	35	(Martinot, 1998)	57	(Torcellini et al., 2004)
14	(Diarra and Akuffo, 2002)	36	(McDowall, 2007)	58	(Tsoutsos and Stamboulis, 2005)
15	(Dieckmann et al., 2004)	37	(Melikov et al., 2007)	59	(Tsoutsos et al., 2005)
16	(Dutton et al., 2005)	38	(Meyers, 1998)	60	(Turkenburg, 2000)
17	(Evans et al., 2009)	39	(Mirza et al., 2009)	61	(Weaver and Forsyth, 2006)
18	(Feustel and Stetiu, 1995)	40	(NRTEE and SDTC, 2009)	62	(Webster, 2005)
19	(Fordham, 2000)	41	(OECD/IEA, 1998)	63	(Woods, 2004)
20	(Friesen, 2008)	42	(Owen, 2006)	64	(Yudelson, 2008)
21	(Gipe, 2004)	43	(Painuly, 2001)	65	(Yuen et al., 2010)
22	(Grant et al., 2008)	44	(Parthan et al., 2009)	66	(Zhang and Yang, 2006)

Table 2-3: Summary of risks, technologies, and references

Risks	EERTs	EETs	RETs	HVAC				Lighting		Solar		Wind
				RS	CB	UFAD	NV	EELB	MS	PV	ST	WT
Aesthetically unpleasing	54		58		51					1, 59	1, 30, 59	1, 17, 21, 22, 41, 60
Bird collision												1, 17, 21, 41, 60
CO_2 suffocation					4							
Dangerous emissions from unit production										1, 41, 59, 60	1	
Draught & thermal discomfort				18	37, 52	10, 28, 62, 63, 66						
Emergence of new and superior technology		23	24, 58									
Fire risk										59	59	
Future change in regional climate and weather fluctuation		23	24							14, 25	45	
Glare risk from collector sunlight reflection										1, 11	1	
Headaches and skin rash								7,8				
Hidden costs		38	48									
Lack of access to funds	35, 54	38	39, 42, 43, 48							60		
Lack of access to information about technology	35, 53, 54	9, 38, 40, 49	39, 43, 48			6, 28, 62, 66				14		61
Lack of access to spare parts	2		39									
Lack of access to the technology		53, 38, 49	39, 43									61
Lack of skilled personnel	2, 13, 35, 44	38, 40, 46	39, 43	64	15, 51	3, 6, 62 66				14, 25	45	
Leakage of hazardous material				36				20			41, 59	

Table 2-3 (*continued*): Summary of risks, technologies, and references

Risks	EERTs	EETs	RETs	HVAC				Lighting		Solar		Wind
				RS	CB	UFAD	NV	EELB	MS	PV	ST	WT
Low consumer demand and acceptance		40 , 46, 49	43, 58, 48			66		27				60
Low product and performance reliability	13, 53	23, 38, 40	24, 39, 43, 48, 58	18		62, 63	57	27, 65	33, 56	14, 17		16, 61
Misplaced incentives	44, 54	9, 38, 40	42, 48								45	
Noise and building vibration												1, 16, 21, 22, 41, 43, 60
Operational failure			24, 58					29				1, 16, 17
Physical degradation										47		
Presence of system constraints			43	18	4, 26, 51, 52	66	34	27, 65				
Slow response rate to temperature changes				64								
Surface condensation and mould growth				18, 64	5, 15, 26	3, 62, 63, 66	19					
Unauthorized building entrance							12, 32, 34, 50					
Uncertain availability of incentives	2, 35, 54	23, 38, 40	48							2	2	2, 61
Uncertain government policies	44, 53, 54	9, 23, 40	31, 39, 43, 48, 58							2	2, 45	2, 60, 61
Uncertain payback period	13	38, 40	43, 48, 55									

2.6 Stakeholder Theory and Analysis

2.6.1 History of stakeholder theory

The word *stakeholder* first appeared in 1963 in an internal memorandum at the Stanford Research Institute (Freeman, 2010). Since then, a number of directions have been developed from the historical path: 1. corporate planning, 2. systems theory, 3. corporate social responsibility, and 4. organization theory (Freeman, 2010). In 1984, Freeman argued the need for a stakeholder approach to strategic management because organizations were experiencing turbulence (Friedman and Miles, 2006).

The stakeholder concept was originally defined by the Stanford Research Institute as "those groups without whose support the organization would cease to exist" (Freeman, 2010). The definition was then improved by others such as Freeman, who defined a stakeholder as "Any group or individual who can affect or is affected by the achievement of the firm's objectives" (Freeman, 2010). Figure 2-11 illustrates a map of a firm that takes into consideration all groups and individuals who can affect or be affected by the achievement of the firm's objectives.

Figure 2-11: Map of a firm and its stakeholders (Freeman, 2010)

2.6.2 Stakeholders classification

Stakeholders can be classified into two groups, either primary or secondary (Clarkson, 1995). A primary stakeholder group is one without which the corporation cannot operate (Clarkson, 1995). Primary stakeholder groups typically include: shareholders and investors, employees, customers, suppliers, and governments and communities (Clarkson, 1995). A high level of interdependence exists between the corporation and its primary stakeholder groups (Clarkson, 1995). On the other hand, secondary stakeholders groups are those who are not involved in transactions with the corporation and are not crucial for its survival but influence or affect, or are influenced or affected by the corporation (Clarkson, 1995). Examples of secondary stakeholder groups are the media and a wide range of special interest groups (Clarkson, 1995). These secondary stakeholder groups have the capability to mobilize public opinion in favour of, or in opposition to, a corporation's performance (Clarkson, 1995).

2.6.3 Aspects of stakeholder theories

Various authors have clarified and used in very different ways the concepts of stakeholder, stakeholder model, stakeholder management, and stakeholder theory, and they applied different and often contradictory evidence and arguments (Friedman and Miles, 2006). For instance, Donaldson and Preston view the stakeholder theory through four theories: descriptive, instrumental, normative, and managerial (Donaldson and Preston, 1995) as follows:

1. Descriptive stakeholder theory: The theory presents a model that describes what the corporation is. Here the corporation is illustrated as a constellation of cooperative and competitive interests possessing intrinsic value.

2. Instrumental stakeholder theory: A framework is established for examining the connection, if at all, between the practice of stakeholder management and the accomplishment of a range of corporate performance goals.

3. Normative stakeholder theory: Presumes the acceptance of two ideas:

    (a) Firstly, stakeholders are individuals or groups with legitimate interests in procedural and/or substantive aspects of corporate activity.

    (b) Secondly, all stakeholders' interests are of intrinsic value, meaning that each group of stakeholders merits consideration for its own sake and not only because of its capability to further the interests of some other groups, like the shareowners.

4. Managerial stakeholder theory: This describes existing situations or predicts cause-effect relationships in addition to recommending attitudes, structures, and practices that, taken together, constitute stakeholder management.

Reed (2002) observes that it is possible to distinguish between definitions of stakeholders on the following logical basis:

1. Descriptive stakeholders are those who could be affected by the firm and/or can potentially affect the firm.

2. Instrumental stakeholders are those who the management need to take into consideration when trying to achieve their goals.

3. Normative stakeholders are those who have valid normative claims on the firm.

A study undertaken in 2009 as an overview of previous studies in stakeholder management shows that papers on the descriptive stakeholder theory approach have increased dramatically since 2005 (Yang et al., 2009), making this stakeholder approach a major focus of stakeholders management research (Yang et al., 2009). The study covered 159 papers published between the years 1979 and 2008 and showed that 54% of these papers focussed on the descriptive stakeholder theory approach (Yang et al., 2009).

2.6.4 Stakeholder Analysis

The stakeholder theory offers a sound base for the identification, classification, and categorization of stakeholders, as well as understanding their behaviour (Aaltonen, 2011). Stakeholder analysis represent a significant component of the stakeholder theory (Aaltonen, 2011; Jepsen and Eskerod, 2009). It is defined as follows: "Stakeholder analysis systematically identifies important groups of people or individuals who can exert a significant amount of influence on the organization and its competitors" (Fleisher and Bensoussan, 2003). It can also be defined as the identification of (1) key project stakeholders, (2) an evaluation of their interest, and (3) how these interests affect the riskiness and viability of a project (ODA, 1995).

Several authors have established different steps for conducting stakeholder analysis. For instance, stakeholder analysis can be done by undertaking the following steps (ODA, 1995): 1. Creating a stakeholder table, 2. Carrying out an assessment of each stakeholder's importance to project success and their power and influence regarding the project, and 3. Identify risks and assumptions that will affect project design and success. Alternatively, it can be simply carried out through the following steps (Maguire et al., 2012): 1. Who? Identifying who should be involved, 2. When? Determining when they should be involved, and 3. How? Establishing how they should be involved.

2.6.5 Stakeholder groups in related literature

Many studies of energy efficient and/or renewable technologies have engaged stakeholders to evaluate these technologies. For instance, in a study of the barriers to the diffusion of renewable energy technologies, the stakeholders were classified into households, industrial firms, commercial establishments, wind energy developers and policy experts (Reddy and Painuly, 2004). Another study of alternative energy technologies in buildings from the stakeholder's viewpoint categorised its stakeholders into 8 groups: architects, building services engineers, clients, specialist consultants, planners, project managers/quantity surveyors, technology suppliers and contractors (Cooke et al., 2007). In a survey that aimed to assess the level of stakeholders' awareness of current energy and environmental issues, and to identify their attitudes to implementing building integrated photovoltaics in Gulf Cooperation Council countries, four stakeholder groups were targeted (Taleb and Pitts, 2009). These stakeholder groups included homeowners, academics, building developers, and architects (Taleb and Pitts, 2009). A study was carried out to investigate the reasons for the absence and scarcity of the implementation of sustainable energy technology in the Kingdom of Bahrain (Alnaser and

Flanagan, 2007). A questionnaire was used to collect data from three stakeholder groups: architects, policy and decision makers, and contractors, that is the triangle of building development (Alnaser and Flanagan, 2007).

2.6.6 Stakeholder analysis in the present research

In the present research, stakeholder analysis will be adopted and used as part of an integrated framework to mainly identify and present those stakeholders of EERTs implemented in green office buildings. The scope of the study will include the primary stakeholder groups. The concept of identifying those stakeholders affected by green office building EERTs and/or those who can affect green office building EERTs will be embraced and will represent an essential part of this research.

To be able to analyse the risks of such technologies, professional and field experts must be approached to evaluate the levels of risk. Hence, architects, contractors, engineers, and project managers involved in green building projects will be invited to evaluate the risks of EERTs implemented in green office buildings. In addition to evaluating EERT risks, they will also be asked to specify the stakeholders affected by each of these risks. These stakeholders will be categorized into the following: architects, contractors, engineers, occupants, owners, project managers, and suppliers. Furthermore, industry practitioners will be approached to identify the managing stakeholders for each of the EERT critical risks.

In the present research, stakeholder analysis will be carried out over the following steps (ODA, 1995):

1. Creating a stakeholder table,

2. Carrying out an assessment of each stakeholder's importance to project success and their power and influence regarding the project, and

3. Identify risks and assumptions that will affect project design and success.

Creating a stakeholder table involves the identification of all potential stakeholders and their interests with regard to the project and its objectives. Also, it includes briefly assessing the likely impact of the project on the stakeholders interest and the priority that should be given to each stakeholder in meeting their interest (ODA, 1995). In this research, stakeholders will be identified through a literature review and surveys with industry practitioners. All stakeholders identified will be primary stakeholder groups and their interests with regard to EERTs implemented in green office buildings will be pinpointed. All types of assessments are going to be done by industry practitioners participating in this research. The priority of meeting the stakeholders' interest is going to be linked to their importance/influence to the project.

The importance of stakeholders in a project is referred to as their problems, needs, and interests. On the other hand, the influence of stakeholders on a project is referred to as the power that they have over a project to control decisions, facilitate its implementation, or exert influence (ODA, 1995). In this research, industry practitioners will conduct the assessment of the importance and influence of EERTs green office building for stakeholders. The assessment of the importance of stakeholders is represented by those who are affected by the risks of EERTs and will be carried out by industry practitioners through questionnaires. The results of the affected stakeholders analysis and findings will be discussed under Sections 4.5.3 and 4.6.3. The assessment of the influence of stakeholders is represented in those who have the ability to manage and control the critical risks of EERTs and will be carried out by industry practitioners through semi-structured interviews. The results of the managing stakeholders' analysis and findings will be discussed under Sections 5.4.4 and 5.5.

Risk identification represents an essential part of this research. The success of a project depends partially on the validity of assumptions made about its different stakeholders and the project risks (ODA, 1995). Risks that are derived from the conflicting interests of stakeholders should also be considered (ODA, 1995). Moreover, it is necessary to define who should participate, how, at what stage of the project lifecycle, in order to contribute to a well designed project (ODA, 1995). In this research, the identification of the risks of EERTs implemented in green office buildings is carried out comprehensively through a literature review and questionnaires. This includes the risks of stakeholders' conflict of interests if any, see Sections 2.5.2, 4.5.1 and 4.6.1 for details. Managing measures of EERTs critical risks are also discussed in this research, including who should manage the critical risk of EERTs (see Section 5.4.4), how to manage these critical risks (see Section 5.4.3), and when, during the lifecycle stages, is it the best time to take action against these critical risks (see Section 5.4.5).

2.7 Lifecycle Asset Management

Like stakeholder analysis, lifecycle asset management represents an essential part of this research. It is defined as: 'The time interval that commences with the identification of the need for an asset and terminates with the decommissioning of the asset or any liabilities thereafter' (NAMS, 2006). Another definition of asset management is "A decision making tool that creates a framework for both long and short-term planning" (Wittwer et al., 2002). It is used for looking after an asset and its requirements throughout its lifecycle.

According to the International Infrastructure Management Manual (IIMM), the lifecycle of an asset consists of the following stages: asset planning, asset creation/acquisition, financial management, asset operation and maintenance, asset condition/performance, asset rehabilitation/replacement, asset disposal/rationalisation, and asset management audit/review (NAMS, 2006). The objective of having this lifecycle asset management process is to look at the lowest long-term cost (see Figure 2-12) (NAMS, 2006).

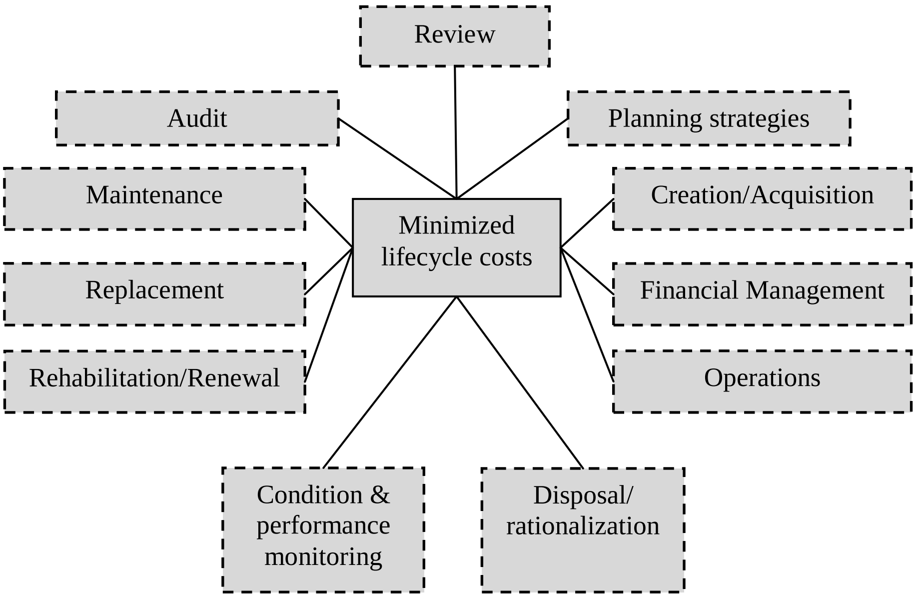

Figure 2-12: Lifecycle asset management (NAMS, 2006)

Following are details of the stages of lifecycle asset management by IIMM (NAMS, 2006):

- *Asset planning stage* involves confirming the service that is required from the customer and making sure that the asset proposed represents the most effective solution to meet the customer's requirements.
- *Asset creation/acquisition stage* involves the provision or enhancement of an asset where the outlay can reasonably be expected to offer benefits further than the year

of outlay. To make the most economic and creative solutions, a value management approach may be adopted.

- *Financial management* involves the identification of all costs related to asset ownership, including creation/acquisition, operation and maintenance, rehabilitation, renewals, depreciation and disposal, and supports cost-effective decision making.
- *Asset operation and maintenance* involves functions that relates to the daily operation and maintenance of assets, and the related costs are mainly significant for dynamic and short-lived assets.
- *Asset condition* relates to the physical condition of the asset, while the performance relates to the capacity of the asset to achieve the target level of service (NAMS, 2006). In order to identify under-performing assets or those which are about to fail, it is important to monitor the asset's condition and performance throughout its lifecycle.
- *Asset rehabilitation/replacement* refers to the major upgrading or replacement of an asset or any of its components to restore it to its required functional condition and performance.
- *Asset disposal/rationalisation* is given in the form of an opinion when an asset is no longer needed or becomes uneconomical to maintain or rehabilitate. It gives the chance to review the configuration, type and location of assets, and the service delivery process related to the activity.
- *Asset management audit/review* aims to ensure a continuous asset management enhancement cycle, and to achieve/maintain suitable industry practice by carrying out regular internal and independent audits.

Similarly to IIMM, a holistic asset lifecycle management model has been established by Schuman and Brent (2005) to manage physical assets throughout their lifecycles. The model is based on three integrated levels: the project management framework, the asset lifecycle, and operational reliability (Schuman and Brent, 2005). The model consists of six components: 1. Identify need for assets, 2. Conceptual and preliminary design, 3. Detail design and development, 4. Construction and/or production, 5. System utilisation and lifecycle support, and 6. Retirement (Schuman and Brent, 2005). Following are the details of the holistic asset lifecycle management model by Schuman and Brent (2005):

- *Identify needs for assets* component is where requirements are investigated and evaluated in a broad sense due to the limited details known of the actual assets.
- *Conceptual and preliminary design* occurs in the detailed investigation stage, where a multi-skilled team of people from operating, production, and maintenance disciplines are involved at early stages to address concern and remove obstacles. They make initial assumptions with respect to the future human capacity and skills required for the operation and maintenance of the facility. Initial assumptions also include preliminary numbers of equipment and the estimated size of the facility. In this stage process flow diagrams are developed to illustrate the basic flow of the process. Materials selection is made and a high level system breakdown structure is created to visualise the functional positions of equipment in accordance with its operation process.
- *Detailed design and development* is where more details are available and the contribution of the operational and maintenance personnel increases. The process flow diagram develops into a mechanical flow diagram that shows all details of equipment including size, materials, and layout to give the requirements for

equipment maintainability. The full version of the system breakdown structure is completed in this stage.

- In the *Construction and/or production* component, the training of operational and maintenance personnel is undertaken. Later the personnel are involved in the asset checkout. This includes conformance to process and maintainability requirements. Finally, suitable reliability strategies are placed for all equipments.
- *System utilisation and lifecycle support of asset* is where continuous improvement is made for effective and efficient operation. Operations are also monitored within the parameters of the asset. Furthermore, management of service contracts and guarantees for work are drawn up. Finally, reliability strategies are implemented and optimised when necessary.
- *Retirement* is the component where the system becomes worn and requires replacement. System retirement should be considered during all stages of system development and when required should be carried out in a way that minimise costs and environmental effects.

2.7.1 Lifecycle stages in related literature

Different studies have different forms of lifecycle processes. For instance, in a study of the lifecycle process of a green building, the lifecycle process consisted of: natural resource extraction, building material production, on-site construction, transportation, operation, maintenance and demolition (Wang et al., 2005). A further example is the lifecycle process in a study that involved the performance assessment of sustainable technologies, where the lifecycle process consisted of: feasibility analysis, conceptual design, detailed design, approvals, tendering, construction, commissioning, absorption, operation and maintenance, renewal and removal (Nelms et al., 2007).

2.7.2 Lifecycle management in the present research

The present research focuses on the risks of energy efficient and renewable technologies implemented in green office buildings. The lifecycle process will be for the asset, comprising of the green office building and EERTs. Industry practitioners will be invited to select the lifecycle stages of risk occurrence from the following list:

- Technology manufacture,
- Building concept,
- Building design,
- Building construction & technology installation,
- Operation & maintenance, and
- Demolition & recycling.

The practitioners will also be approached to identify the lifecycle stages of action against the critical risks of EERTs.

2.8 Identification of Research Gaps

EERTs are an essential part of green buildings, and the above literature review presents the work of several researchers in different fields to highlight this significance. It is clear that a number of researchers have explored EERTs and their risks but none have explored them systematically and comprehensively. Furthermore, none of the previously undertaken studies have investigated the integration of the risks of EERTs with stakeholders and lifecycle asset management for the purpose of managing these risks as part of the process. This includes identifying the risks to affected and managing stakeholders as well as the lifecycle stages of risk occurrence and the lifecycle stages of actions against the risks. The Australian green building industry is relatively new and stakeholders in this industry are seeking to avoid costly mistakes when dealing with these EERTs. In addition, industry practitioners may be reluctant to implement EERTs due to their risks. In Australia, office buildings produce the highest amount of CO_2 emissions per annum compared to buildings types such as schools and hospitals (AGO, 1999). Thus, they have attracted great attention in converting them into green office buildings.

As a result of the literature review, a research problem has been defined – *Energy efficient and renewable technologies (EERTs) have been available in the market for a while now but appear to be not applied widely. What are the risks pertaining to EERTs which obstruct their wide application in Australian green office buildings?* From this research problem six research questions have been derived: 1. *What are the critical risks that stakeholders may face when using EERTs in Australian green office buildings?* 2. *Do different industry practitioners share the same opinions of the risks associated with EERTs implemented in green office buildings?* 3. *For each critical EERT risk, who are the affected stakeholders and who are the stakeholders responsible for treatment?* 4. *For each critical EERT risk, what are the affected lifecycle stages of risk occurrence and what are the lifecycle stages of action against these critical risks?* 5. *How can these critical risks be managed in the process of implementing EERTs for green office buildings?* 6. *How can green office building stakeholders be well guided in managing EERTs critical risks in a preventative manner?*

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter provides details of the methodology and design of the present research. In order to determine the most suitable research methodology approach and design, logic must be critically considered as it links the data collection and analysis to produce results and hence conclusions to the research questions (Fellows and Liu, 2008). Ensuring that the research maximises the chances of achieving the research objectives is the key priority (Fellows and Liu, 2008). Thus, taking into consideration the research questions, type of data required, and data analysis method is necessarily in the research design (Fellows and Liu, 2008).

Identifying the critical risks of EERTs implemented in green office buildings and exploring the methods to manage these critical risks are the main aims of this research. In order to answer the research questions and achieve the research objectives, a comprehensive research process was planned and carried out. A combined survey and case studies approach was selected, and the survey included two methods: a questionnaire and a semi-structured interview. The questionnaire was mainly designed to investigate the opinions of industry practitioners with regard to EERT risks in the Australian environment. The semi-structured interviews were designed to explore management measures in relation to EERT risks. The purpose of the case studies was to validate all of the research outcomes in the form of a framework applied to functioning Australian green office buildings.

This chapter provides discussion of all steps of the research process. It covers details of the research design, the research process, the data collection methods and their development, the data analysis, and the formulation of study framework.

3.2 Research Design

Decisions are made in the research design step on the methodological approach to finding solutions to the research problem or questions (Fellows and Liu, 2008). Research design entails detailing the approaches by which the research objectives are to be accomplished by the researcher (Fellows and Liu, 2008). The research design contains six fundamental aspects: purpose of the study, type of investigation, extent of research interference, study setting, unit of analysis and time horizon (Sekaran, 2003). Figure 3-1 presents the research design and its contents.

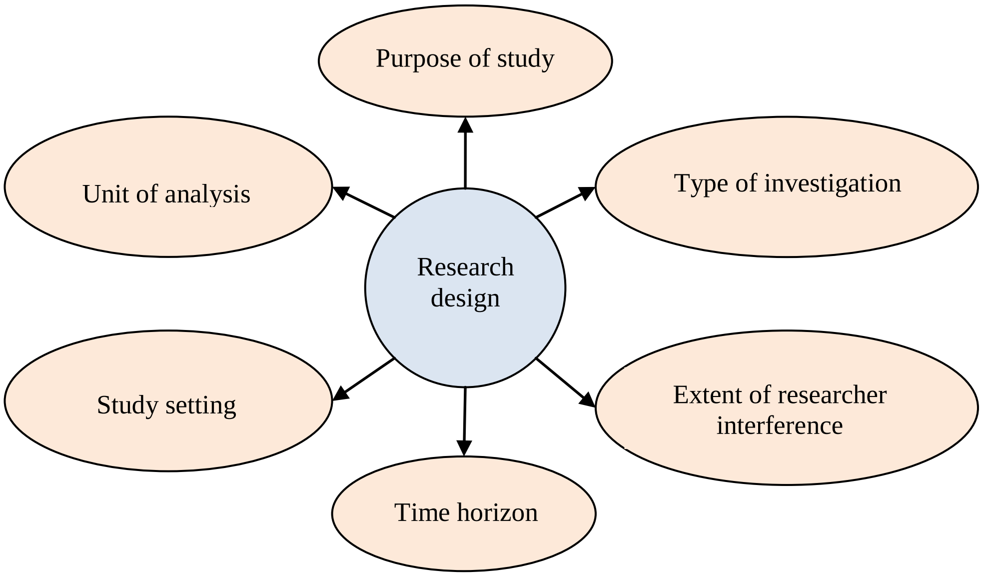

Figure 3-1: Content of research design (Sekaran, 2003)

3.2.1 Purpose of the study

The purpose of a study may be exploratory, descriptive or hypothesis-testing and the nature of the study depends on the level of knowledge reached on the research topic (Sekaran, 2003). An exploratory study is conducted when there is a lack of information on the existing situation or how to solve similar research problems that occurred in the past (Sekaran, 2003). Furthermore, exploratory studies occur in areas where very few studies have been carried out previously (Sekaran, 2003). Performing extensive preliminary work in order to gain awareness of the phenomena in the situation and to understand what is happening needs to be done in such cases, before the development of a model and the creation of an accurate design for a complete investigation (Sekaran, 2003).

The purpose of this research is to create a critical risk management framework for the implementation of EERT in Australian green office buildings. This includes exploring EERT critical risks and measures to manage them. Therefore, given the lack of previous research in this area, this research can be classified as an exploratory type study.

3.2.2 Type of investigation

The type of investigation can be either causal or correlational (Sekaran, 2003). Causal studies are those where the researchers want to define the causes of one or more issues (Sekaran, 2003). On the other hand, correlational studies are those where the researcher is seeking to define the important variables linked with the issue (Sekaran, 2003). Whether an investigation is causal or correlational depends on the type of research question and the way the problem is defined (Sekaran, 2003).

The objectives of this research are to identify the important variables related to the problem, making the type of investigation a correlational study.

3.2.3 Extent of researcher interference

The extent of research interference with the usual flow of work at a workplace has a direct relationship with whether the study being carried out is causal or correlational (Sekaran, 2003). In a correlational study, the researcher has minimal interference with the usual flow of work in the natural environment of the organization (Sekaran, 2003). Some disruption occurs to the usual flow of work at the workplace as the researcher interviews employees and administers questionnaires but this interference is considered to be minimal compared to causal studies (Sekaran, 2003). On the other hand, in studies that work on establishing cause and effect relationships, deliberate manipulation of certain variables is done by the researcher to study their effect on the dependent variable of interest (Sekaran, 2003).

In this research, minimal interference was caused to the working environment of the industry practitioners involved in the data collection stage, as they completed the questionnaires or answered the questions during interviews.

3.2.4 Study setting

Study settings can be contrived or non-contrived (Sekaran, 2003). Contrived settings are studies with artificial and non-natural work environments, whereas non-contrived settings are studies with natural conditions where work proceeds normally (Sekaran, 2003). Correlational studies are conducted in non-contrived settings and causal studies are done in contrived settings (Sekaran, 2003).

The study setting for this research was noncontrived, due to the minimal interference of the researcher with the flow of the working environment. In addition, it was non-contrived due to it being a correlational study.

3.2.5 Unit of analysis

According to Sekaran (2003), the unit of analysis is "the level of aggregation of the data collected during the subsequent data analysis stage". The unit of analysis is determined by the research questions (Sekaran, 2003). For instance, if the researcher is interested in studying the motivational levels of individual employees in an organization, the unit of analysis is individual (Sekaran, 2003). If the researcher wants to study the interaction between two persons, then the unit of analysis will be dyads (Sekaran, 2003). If the researcher wants to study group effectiveness, then the unit of analysis will be groups (Sekaran, 2003).

The data used in this research were collected from industry practitioners through questionnaires and semi-structured interviews. Hence, the unit of analysis was the industry.

3.2.6 Time horizon

There are two types of time horizon studies: cross-sectional or longitudinal (Sekaran, 2003). Cross-sectional studies are those studies where the data required for answering the research questions are gathered only once, possibly over a period of days, weeks or months (Sekaran, 2003). On the other hand, longitudinal studies are those studies where the data required for answering the research questions are collected at more than one point in time (Sekaran, 2003).

The research data for the present study were collected once from industry practitioners over a period of weeks. Therefore, this research was a cross-sectional study.

3.3 Research Process

This section presents the detailed approaches used in the research to answer the questions and achieve the objectives. The research process is illustrated in Figure 3-2, where a model incorporating the detailed approaches is revealed. The model includes four different stages with four different levels. Stage One involves the literature review and its outcomes, Stage Two the questionnaire and its outcomes, Stage Three the semi-structured interviews and their outcomes, and Stage Four the creation of the framework and the case studies outcome. The four levels are data collection methods, analysis and findings, questions answered, and objectives achieved.

In the first stage of the research process a comprehensive literature review was carried out. It included the identification of the most common EERTs implemented in Australian office buildings by exploring and reviewing the technologies that are used in the sample of Australian green office buildings. In addition, research literature related to the risks of these EERTs was reviewed to identify the risks.

The second stage included the questionnaire, where the risks identified from the literature review were evaluated by industry practitioners to identify the most critical risks of EERTs. Furthermore, the differences in risk perceptions of the industry practitioners were explored. In addition, the industry practitioners were asked to identify those stakeholders impacted by each risk, as well as the likely lifecycle stages of risk occurrence. Research questions one and two were fully answered by the end of this stage, while questions three and four were partially answered. Similarly for the research objectives, objectives one and two were fully achieved, while objectives three and four were partially achieved by this time.

The third stage involved the participation of industry practitioners in semi-structured interviews. They were asked to propose measures to manage the critical risks of EERTs, and to reveal the causes and impacts of these critical risks. In addition, the industry practitioners selected the stakeholders to manage the critical risks of EERTs and the lifecycle stage of action against the critical risks. Research questions three, four, and five were fully answered by the outcome of this stage. Likewise, research objectives three, four, and five were fully achieved by this stage.

Stage four included the creation of the research framework which incorporated all of the research findings from the previous three stages. The framework was created based on three aspects of the research literature; risk management process, stakeholder analysis, and lifecycle asset management. Finally, the framework was validated on two Australian green office buildings using case studies. Research question six was fully answered by the outcome of this stage. Similarly, the sixth objective of the research was fully achieved by the accomplishment of this stage.

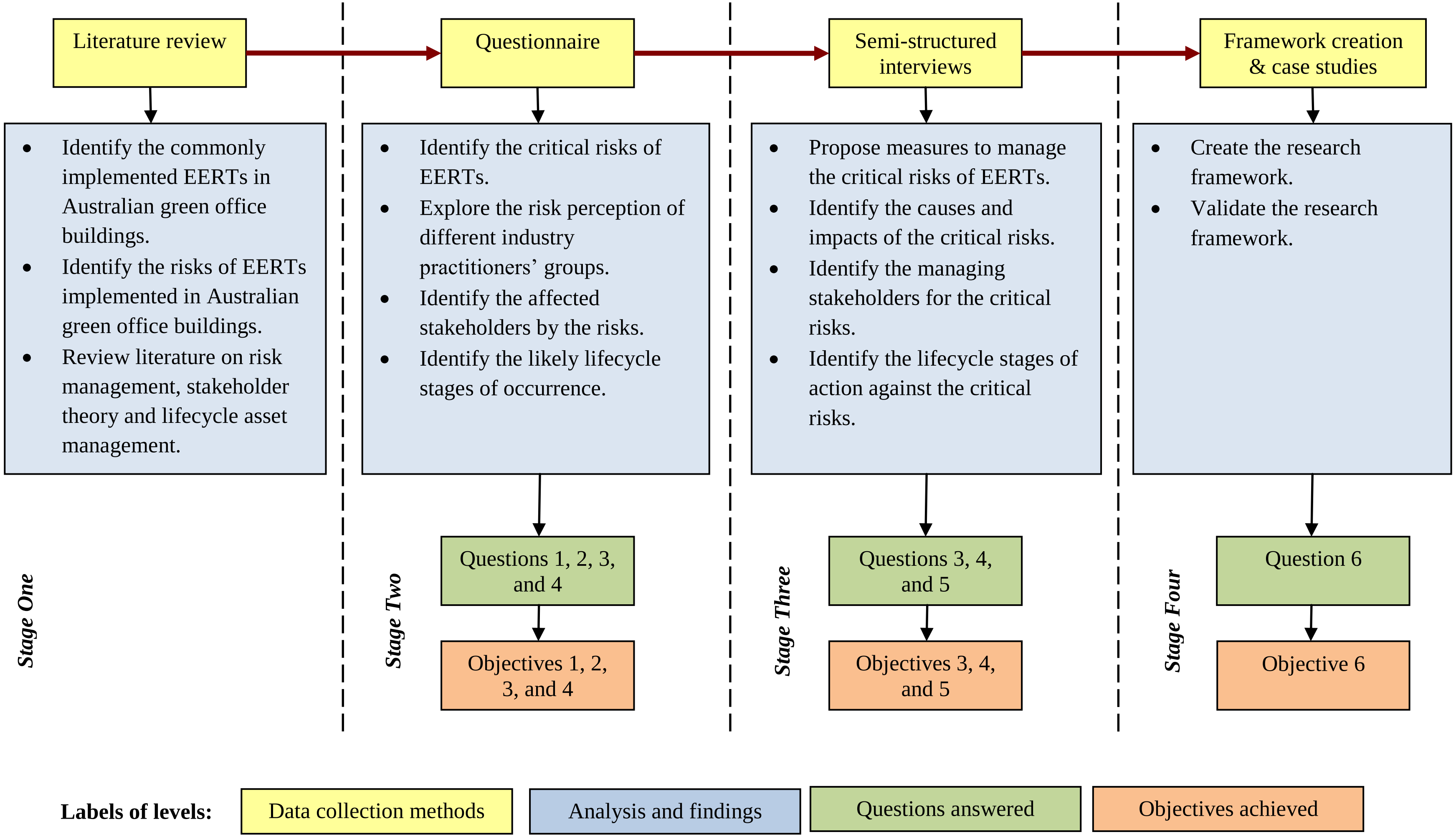

Figure 3-2: Research process

3.4 Data Collection Methods

The data collection methods for this research were from both primary and secondary sources, where primary sources refer to those data acquired by the researcher on the variables related to the study (Sekaran, 2003). On the other hand, secondary sources refer to those data acquired from sources that already exist (Sekaran, 2003). The primary sources of data included questionnaires, semi-structured interviews and case studies, while the secondary source of data was the literature review.

3.4.1 Literature review

Literature review is the comprehensive citations by the researcher of published and unpublished work from secondary sources of data in the particular area of the researcher interest (Sekaran, 2003). Books, journals, newspapers, magazines, conference proceedings, government publication, doctor dissertations, master's thesis, financial, marketing, and other reports are used by the researcher over several week or months to find information on their research topic (Sekaran, 2003). The principal behind literature review, is to ensure that all previous found variables that are related to the research problem are identified in the study (Sekaran, 2003). Literature review should address all relevant information in a convincing and rational approach (Sekaran, 2003).

The literature review for this research has been provided in Chapter 2. It covered books, journals, magazines, conference proceedings, government publications and various reports, and included different areas related to the research, as follows: green buildings, EERTs, risks of EERTs, risk management process, stakeholder analysis and lifecycle asset management.

3.4.2 Questionnaires

A questionnaire is efficient when the researcher is aware of what exactly is required and how to measure the targeted variables (Sekaran, 2003). Questionnaires can be distributed in many ways including: personally administered, mailed or web-based. Personally administered questionnaires are a good method to collect data if the survey has to be done in a confined local area with an organization that is able and willing to gather a group of employees in order to respond to the questions (Sekaran, 2003). This allows collection of the completed responses in a short period of time, and enables the clarification of any doubts that the respondent might have on the spot (Sekaran, 2003). Mail questionnaires are mailed to the respondents, giving them the freedom to answer the questions at their convenience in their homes and at their own speed (Sekaran, 2003). Mail questionnaires are helpful because they can cover a wide geographical area in the survey. On the other hand, the response rate is typically low and a rate of 30% is considered adequate (Sekaran, 2003). Web-based questionnaires provide many facilities for designing a questionnaire that cannot be achieved by paper-based questionnaires, including dropdown menus, pop-up instruction boxes, and sophisticated skip patterns (Gray, 2009).

Web-based questionnaires were used in this research in the process of data collection, due to the lack of available data on the risks of EERTs implemented in Australian green office buildings. It was intended that the responses would help in forming a database for the analysis stage. A web-based questionnaire was designed and a link to the questionnaire website was created. The link was then sent to industry practitioners in eight of Australia's states and territories where green office building exists. Data collection took place between July and August of 2010. The following states and territories were included: the Australian Capital Territory, New South Wales, Northern Territory, Queensland, South

Australia, Tasmania, Victoria, and Western Australia. The questionnaire sample size was calculated by using an online sample size calculator created by National Statistical Services (NSS, 2010). The confidence level was selected to be 95%, the confidence interval 0.05, and the population size which refers to the number of experts in the industry was 50,000. The result was a sample size of 382. This sample size represents the minimum sample to be approach by the researcher, any increase in the sample size will not affect the analysis but any decrease in the sample size will affect the analysis. The author selected to increase the sample size to 400 and had more people participating in the research.

3.4.3 Semi-structured interviews

Interviews are a data collection method used to gather information on a particular issue (Sekaran, 2003). Interviews can be structured, semi-structured, and unstructured (Fellows and Liu, 2008). Structured interviews are administrated by the interviewer, and may be in the form of a questionnaire that includes a set of questions asked of the interviewees and their replies are recorded (Fellows and Liu, 2008). Semi-structured interviews are between the two previous types (Fellows and Liu, 2008). They can range in their form from a questionnaire to a list of topics discussed by the respondent (Fellows and Liu, 2008). Interviews can be conducted in several ways: face-to-face, by telephone or computer-assisted (Sekaran, 2003).

Semi structured interviews were adopted in this research after the questionnaire stage was completed, and the results of the questionnaire stage were used to set the questions for the semi-structured interviews. The main purpose of the semi-structured interviews was to find measures to manage the critical risks of EERTs implemented in green office buildings. Industry practitioners with sound experience were approached to participate in the semi-structured interviews. Judgment sampling was used for the semi-structured interviews sample. This sampling involves the selection of participants who are the most advantageously placed or the most suitable to provide the interviewer with the information required (Sekaran, 2003). This sampling method is used when the information required can only be obtained from a limited number or category of people (Sekaran, 2003), which was the case for the present study. Thus, a sample of 20 knowledgeable industry practitioners was approached for this stage of data collection. The semi-structured interviews were undertaken between November and December of 2010 and February and March 2011.

3.4.4 Case studies

According to Yin (2003) a case study is defined as "the method of choice when the phenomenon under study is not readily distinguishable from its context". A project or program might represent the phenomenon in an evaluation study (Yin, 2003). Case studies tend to be much more specific in focus compared to surveys, where large amounts of data have to be gathered, usually from a large, diverse, and widely-distributed population (Gray, 2009). Case studies can be used for a wide range of issues, such as the evaluation of training programs, organizational performance, project design and execution, policy analysis, and relationships between different organizations or different sectors in an organization (Gray, 2009). In a case study, the investigator must have the ability to respond quickly to the answers of the participants and create new questions or issues (Gray, 2009).

Two case studies were conducted at the end of the present research to validate the research framework. The research framework incorporated all the findings of the research stages, including the literature review, the questionnaire, and the semi-structured interviews. Consequently, the validation of the framework validated all of the research findings. The case studies were done on two six star certified Australian green office buildings that implements most of the EERTs discussed in this research. The buildings were selected to be very compatible with the research elements, in order to reflect a realistic case for the validation of the framework. The case studies were undertaken in November 2011.

3.5 Development of Data Collection Methods

The development of the data collection methods used in this research, the questionnaires, the semi-structured interviews and the case studies are presented in the following sections.

3.5.1 Questionnaire development

The questionnaire was developed in order to achieve the following research objectives:

1. Identify critical risks pertaining to the design, construction and through-life cycle of EERTs in Australian green office buildings.
2. Explore the different risk perceptions among the industry expert groups.
3. Identify the affected stakeholders of the EERT risks of Australian green office buildings.
4. Identify the likely lifecycle stages of occurrence for the EERT risks of Australian green office buildings.

The questionnaire consisted of three parts. Part one included demographic questions, Part two questions on risks evaluation, and Part three questions on stakeholders and lifecycle stage.

Research objective one was achieved by the analysis of the findings of Part two of the questionnaire. Research objective two was achieved by the analysis of the findings of Parts one and two of the questionnaire, and research objectives three and four were achieved by the analysis of the findings of Part three of the questionnaire. A quantitative research approach was followed to achieve the questionnaire objectives.

The questionnaire was created electronically using the SurveyMonkey website. Questions were asked in four different formats: multiple choice, drop-down menu, matrix of choice, and open-ended. To view the full content of the questionnaire, refer to Appendix 1.

3.5.1.1 Examples of questionnaire questions

<u>A multiple choice question from Part one of the questionnaire:</u>

Q1. Which of the following energy efficient and renewable technologies have you installed or experienced in your home or workplace? (You can select more than one option)

□ Chilled beams	□ Radiant systems	□ Underfloor air distribution
□ Wind turbines	□ Motion sensors	□ Energy efficient light bulbs
□ Solar thermal systems	□ Photovoltaic panels	□ Night purge and natural ventilation

<u>A drop-down menu question from Part 2 of the questionnaire:</u>

Q1. Based on your knowledge and experience, please indicate the likelihood of occurrence for each of these listed risks and its impact on the stakeholders:

	Likelihood of occurrence	Impact on stakeholders
Uncertain payback period	*Dropdown menu*	*Dropdown menu*
	Rare Unlikely Possible Likely Almost certain Not applicable	Negligible Minor Moderate Major Severe Not applicable

<u>A matrix of choice question from Part three of the questionnaire:</u>

Q1. Based on your knowledge and experience, please indicate the stakeholders affected by the risk of EERTs. You may select more than one option:

	Architect	Engineer	Project manager	Supplier	Contractor	Occupier	Owner
Uncertain payback period	□	□	□	□	□	□	□

3.5.1.2 Pilot study

A pilot study was conducted among industry practitioners before the distribution of the questionnaires. The pilot study took place in June 2010. The questionnaire was piloted by two senior academic researchers and an HVAC engineer, and constructive feedback was obtained to improve the questions and their comprehension. Feedback included corrections of question layout, typing errors, and table formats. All suggestions were incorporated before the distribution of the questionnaire.

3.5.2 Semi-structured interview development

The semi-structured interview was developed in order to achieve the following research objectives:

1. Recognize the responsible stakeholders of EERTs critical risks in green office buildings.

2. Classify the lifecycle stages of action to manage the critical risks of green office buildings EERTs.
3. Find appropriate approaches to manage the critical risks identified.

The semi-structured interview consisted of a total of four questions asked in the context of each of the 14 critical risks identified from the questionnaire findings. All of the semi-structured interview questions were open-ended, giving the participants the chance to provide detailed answers with supporting examples for each. Each interview lasted was between 60 minutes and 90 minutes. To view the full content of the semi-structured interview, refer to Appendix 6. A qualitative research approach was followed to achieve the semi-structured interview objectives.

3.5.2.1 Example of semi-structured interview question

Q1. For each of the listed critical risks, what are the causes of the critical risk?

3.5.3 Case studies development

The case studies were developed in order to achieve the following research objective:

1. Develop an integrated framework encapsulating critical risks and solutions to provide informed advice to stakeholders.

The case study questions were divided into two Parts, A and B, and Part A included questions that investigated the validity of the framework and the collection of comments and useful information from the participants. Part B included questions that rated the characteristics of the framework by using Likert scales. To view the full content of the case studies questions, refer to Appendix 12.

3.5.3.1 Example of case study question

Part A) Q1. Please give your comments on the proposed framework.

Part B) Q1. The framework is clear and easy to use 1 2 3 4 5

3.6 Data Analysis

Following data collection, data analysis was carried out to answer the research questions and achieve the study objectives. Data analysis for the questionnaires was undertaken using quantitative analysis, while data analysis for the semi-structured interviews and the case studies were undertaken using qualitative analysis. Before data analysis was carried out, data preparation was done, including data editing, handling blank responses, coding, categorizing, and data entry (Sekaran, 2003).

3.6.1 Questionnaire

Research questions one and two were fully answered, while questions three and four were partially answered by the analysis of the survey questionnaire. The analysis was divided into four parts, where each part was allocated to the analysis of one research question. The analysis was done quantitatively with the aid of Statistical Package for the Social Sciences (SPSS) software, Version 17.

Part one of the analysis was dedicated to answering Question one of the research. The critical risks of EERTs were identified by using descriptive statistics and error bars for the graphical presentation of the results. Part two was associated with Question two of the research. An ANOVA test was used in order to explore the differences in risk perceptions for the different industry groups participating in the survey questionnaire. Part three of the analysis was related to Question three of the research. To identify the stakeholders affected by the risks of EERTs, a Chi-square test was executed on the data. Part four of the analysis related to Question four of the research. Similarly to Part three, a Chi-square test was used to identify the likely lifecycle stages of occurrence of the risks of EERTs.

3.6.2 Semi-structured interview

In the analysis of the semi-structured interviews, the unanswered parts of Questions three and four were fully answered, and Question five was fully answered. The analysis was divided into four parts, and each part answered one of the interview questions. The analysis of the semi-structured interviews was done qualitatively with the aid of NVivo software, Version 9. This included the use of frequency count.

All semi-structured interviews were recorded using a digital voice recorder. Recordings were downloaded into a computer in the format of audio files that were saved into a special NVivo folder. The interview audio files were then transcribed into the software. Nodes representing the important points related to answering the questions of the semi-structured interviews were created for each of the audio files. NVivo assisted in organizing the files and made the analysis easier as access to information was fast and efficient.

3.6.3 Case studies

The analysis of the case studies was carried out using a qualitative approach. Its main purpose was to validate the research framework and collect any information that could be useful if added to the framework.

Similarly to the semi-structured interviews, the case studies were recorded using a digital voice recorder. Audio files containing the voice recordings were then downloaded into the computer and saved in NVivo’s special folder. Each case study audio file was transcribed into the software. Important points related to answering the questions of the case study were pinpointed by nodes in the audio files for easy and fast access to answers.

3.7 Formulation of Research Framework

The framework was formulated based on the significant findings of the questionnaires and semi-structured interviews. It was created based on three theories: risk management process, stakeholder analysis, and lifecycle asset management. A practical guide to the framework was also created for more detailed information. The framework will assist all stakeholders of Australian green office building EERTs in managing their critical risks. The framework guide consists of six steps: 1. Communication and consultation, 2. Establish the context, 3. Identification, 4. Risk analysis and evaluation, 5. Treatment, and 6. Monitor and review.

CHAPTER 4: QUESTIONNAIRE DATA ANALYSIS AND FINDINGS

4.1 Introduction

Chapter 2 revealed the existence of wide range of risks for the implementation of EERTs in green office buildings and the lack of research investigating or addressing these risks, in the Australian context. This leads to the initiation of the questionnaire in the second stage of the study. A questionnaire survey was created and circulated among industry practitioners in the field of green buildings, with the aim of exploring different aspects of the risks of EERTs implemented in green office buildings and evaluating them.

This chapter presents the data analysis and findings of the questionnaire survey, which explored four areas related to EERT risks: 1. Risk analysis and evaluation, 2. Risk perceptions among different industry practitioners, 3. Identification of affected stakeholders, and 4. Identification of likely lifecycle stages of impact. All analysis was conducted using SPSS software. The outcomes represent a considerable contribution to the field of green buildings as they explore and analyses the risk perceptions of 165 professional practitioners in this field.

4.2 Purpose of Questionnaire

The questionnaire survey was created with the following objectives:

1. Identify critical risks pertaining to the design, construction and through-lifecycle of EERTs in Australian green office buildings.

2. Explore the different risk perceptions among the industry expert groups.
3. Identify the stakeholders affected by Australian green office building EERT risks.
4. Identify the likely lifecycle stages of occurrence for the EERT risks of Australian green office buildings.

4.3 Sample Profile

The response rate of the survey questionnaire was 41.25%, and a total of 165 industry practitioners, including 40 architects, 67 engineers, 42 project managers, and 16 contractors participated. Architects and project managers participated in approximately equal numbers, and the participants' profile is presented in graphic form Figure 4-1.

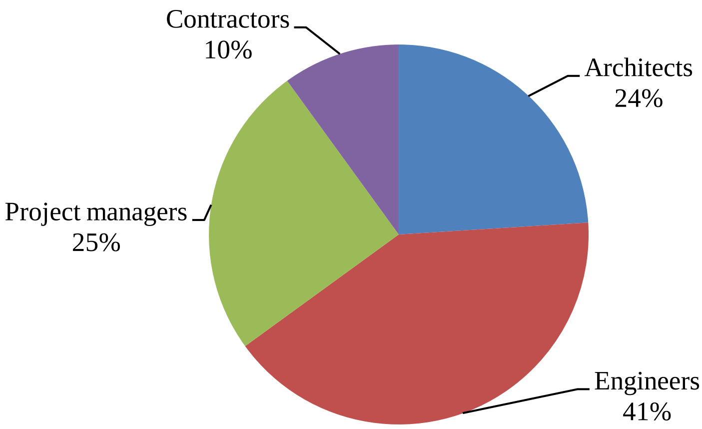

Figure 4-1: Participants' profile

Most of the participants had received higher education qualifications. While three were secondary school certificate holders, 12 had TAFE/college diplomas, 80 held undergraduate degrees, 68 had postgraduate degrees, and two held other degrees. The participants' educational profile is illustrated in Figure 4-2.

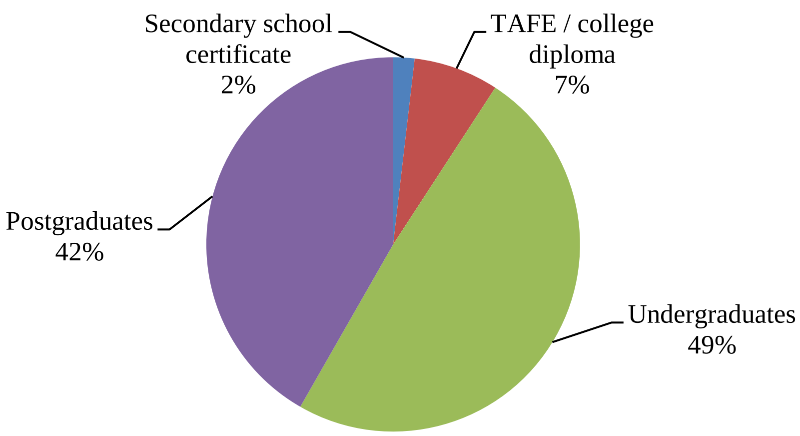

Figure 4-2: Education profile of participants

With respect to length of work experience in the construction industry, 39 respondents had between 1-5 years, 31 between 6-10, 29 between 11-15, and 66 had more than 15 years of experience. The three participants who had no tertiary qualifications had over 15 years work experience, and their feedback was highly appreciated. In general, 76% of the participating industry practitioners had more than five years of industry experience, with 40% of the whole sample having more than 15 years of industry experience, illustrating the contribution of the most experienced in this research. The participants' work experience profile is presented in Figure 4-3.

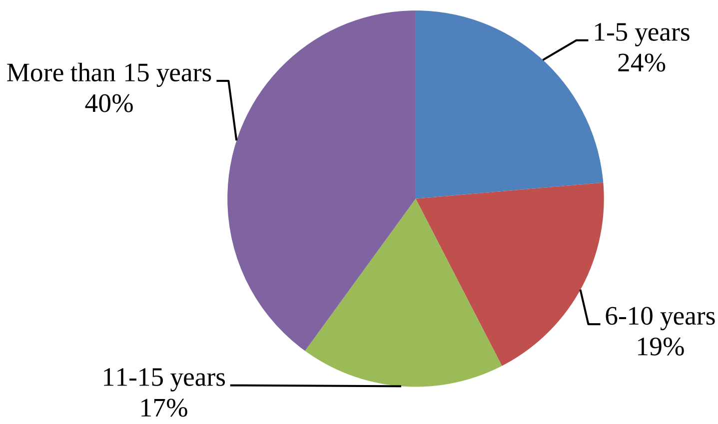

Figure 4-3: Work experience profile of participants

With respect to the number of green building projects with which these practitioners had been involved, 12 had limited experience with green building projects, 73 had experience with 1-4 projects, 30 with 5-10 projects, and 50 with more than 10. Overall, approximately half of the participants had been involved in five or more green building projects, and almost a third of the total participants had been involved in more than 10 green building projects. These figures indicate the involvement of key personnel from the green building industry in the survey. The participants' involvement with green building projects is presented in Figure 4-4.

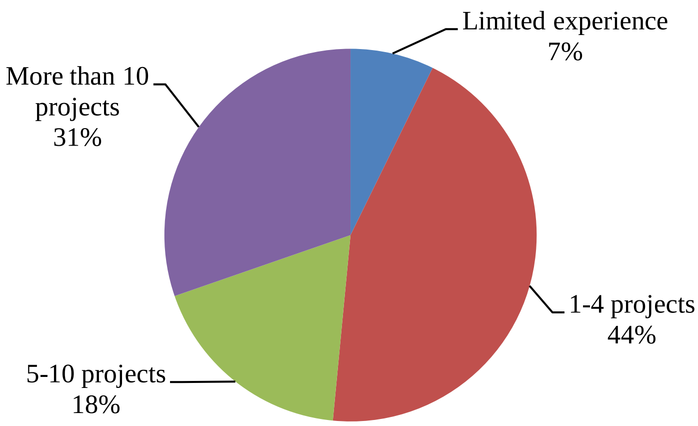

Figure 4-4: Participants' involvement with green building projects

4.4 Data Reliability

Cronbach's Alpha test was carried out on the questionnaire data as it is considered as the most accepted method for examining data reliability (Hinton et al., 2004). The following cut-off points can be used as a guide to interpret the test results (Hinton et al., 2004): 1) equal or above 0.90 indicating excellent reliability, 2) 0.70 to 0.90 indicating high reliability, 3) 0.50 to 0.70 indicating moderate reliability, and 4) below or equal to 0.50 indicating low reliability. The results of the reliability test are shown in Table 4-1.

Table 4-1: Data reliability analysis

Risk evaluation data source	Cronbach's Alpha
Chilled beams	0.902
Night purge and natural ventilation	0.925
Radiant system	0.908
Underfloor air distribution	0.928
Energy efficient light bulbs	0.917
Motion sensors	0.937
Photovoltaic panels	0.937
Solar thermal heating	0.949
Wind turbines	0.929
Stakeholders	0.969
Lifecycle stages	0.970

The Cronbach's Alpha values for all of the collected data are larger than 0.90 which indicates an excellent reliability outcome for all of the data used in this study.

4.5 Questionnaire Data Analysis

The data analysis is divided into four parts, with each part representing the analysis of one of the questionnaire objectives.

The first part covers the identification of the critical risks of EERTs implemented in Australian green office buildings. A semi-quantitative approach was used for the analysis of all 30 risks. The identified critical risks are considered to be the most significant obstacles in the way of EERT implementation in Australian green office buildings. It is hoped that, by identifying them, awareness will be increased and diagnosis can start in the succeeding step to reduce the risks or even eliminate them.

The second part reports on the comparison of industry practitioner risk perceptions for EERTs. It points out the significant differences in perceptions among different industry practitioners. Hence, the industry practitioners with the highest and lowest concerns about EERT risks are identified.

The third part concerns the identification of the affected stakeholders. In this part, stakeholders affected by the risks of EERTs are identified according to the judgement of the industry practitioners. The results also present the rank at which the stakeholders are affected by each risk of EERTs.

The fourth part covers the identification of the likely lifecycle stages of risk occurrence. In this part, the likely lifecycle stages of risk occurrence for each risk are identified according to the judgement of the industry practitioners, and the rank of the occurrence of the likely lifecycle stages for each risk is presented.

4.5.1 Part one: Identification of critical risks

The risks associated with each technology were assessed based on the magnitude of consequence and the likelihood of occurrence. Five options were defined to measure the likelihood of occurrence: rare, unlikely, possible, likely, and almost certain. Similarly, five options were offered to measure the magnitude of consequence: negligible, minor, moderate, major, and severe. All of the risks identified in the literature review process (30 risks) are evaluated. See Chapter 2 for details.

Risk analysis can be done through three approaches, qualitative, semi-quantitative, or quantitative analysis (AS/NZS, 2004). Qualitative analysis is any method that defines the level of risk by using description rather than numerical means. This indicates that both consequence and likelihood use word description in a risk ranking table (AS/NZS, 2004).

In the quantitative method, the consequence and likelihood can be quantified and so the level of risk can be calculated (AS/NZS, 2004). Semi-quantitative method uses a similar approach to qualitative representation with some form of mathematical manipulation (AS/NZS, 2004).

Critical risks were identified using a semi-quantitative approach, where the level of risk impact was calculated by Equation 4-1 (AS/NZS, 2004).

Equation 4-1: **Calculation of level of risk**

$$\boldsymbol{Level\ of\ risk = Consequence \times Likelihood}$$

In order to measure the level of risk for each technology and to know whether they were critical or not, a risk matrix was adapted and developed from an already established risk matrix. This is because the relationship between the consequence and likelihood in a certain risk matrix may differ from one application to another (AS/NZS, 2004). The reference risk matrix was obtained from a study by John Mankins who described a new concept for the integration of the technology readiness levels and the risk matrix for new technologies (see Table 4-2) (Mankins, 2009). The new matrix created for the present study (see Table 4-3) was based on the aforementioned risk matrix. Some amendments were made, including changing the term for the maximum level of risk from high to critical. Furthermore, the study matrix was made to be more conservative and so, critical risk level is assigned for any risk that lays (1) greater than moderate for consequence and at the same time greater than possible for likelihood, or (2) equal to moderate for consequence and greater than possible for likelihood and vice versa. Due to the increase in the critical zone from one end of the matrix a similar increase was made from the opposite end of the matrix represented in the low zone to preserve the symmetric of the matrix.

Table 4-2: Risk matrix by Mankins

Likelihood	**Consequence**				
	Negligible (1)	Minor (2)	Moderate (3)	Major (4)	Severe (5)
Almost certain (5)	Medium	Medium	High	High	High
Likely (4)	Medium	Medium	Medium	High	High
Possible (3)	Low	Medium	Medium	Medium	High
Unlikely (2)	Low	Low	Medium	Medium	Medium
Rare (1)	Low	Low	Low	Medium	Medium

Table 4-3: Risk matrix

Likelihood	**Consequence**				
	Negligible (1)	Minor (2)	Moderate (3)	Major (4)	Severe (5)
Almost certain (5)	Medium	Medium	Critical	Critical	Critical
Likely (4)	Low	Medium	Critical	Critical	Critical
Possible (3)	Low	Medium	Medium	Critical	Critical
Unlikely (2)	Low	Low	Medium	Medium	Medium
Rare (1)	Low	Low	Low	Low	Medium

According to the study risk matrix, the cut-off points are as follows:

Level of risk impact ≤ 4, then the risk will be considered low,

$4 <$ Level of risk impact ≤ 10, then the risk will be considered medium,

$10 <$ Level of risk impact, then the risk will be considered critical.

The final level of risk impact was calculated for each risk pertaining to the nine EERTs by taking the average risk score from all participants. Table 4-4 illustrates the EERT risks and the technologies to which these risks may apply.

Table 4-4: Risks of EERTs with their mean risk impact values

Risk	HVAC				Lighting		Solar		Wind
	CB	NV	RS	UFAD	EELB	MS	ST	PV	WT
Aesthetically unpleasing	6.98	5.83	6.5	5.88	7.03	5.26	8.08	7.46	9.36
Bird collision									6.65
CO_2 suffocation	4.6		3.83						
Dangerous emissions from unit production							5.18	5.93	
Draught & thermal discomfort	7.12	8.08	6.6	6.94					
Emergence of new and superior technology	7.76		7.8	6.84	8.14	7.17	*11*	*11.73*	*10.24*
Fire risk							4.9	4.54	
Future change in regional climate and weather fluctuation	5.83	7.96	6.37	5.27			8.2	*10.19*	*10.42*
Glare risk from collector sunlight reflection							6.7	6.93	
Headaches and skin rash					3.51				
Hidden costs	9.16	7.87	*10.18*	9.37	3.69	4.49	9.38	9.77	*11.11*
Lack of access to funds	*11.57*	9.42	*12.20*	*10.59*	4.41	5.65	*12.75*	*13.31*	*12.87*
Lack of access to information about technology	7.05	6.04	6.97	7.14	3.4	3.8	7.95	8.18	8.64
Lack of access to spare parts	6.69		6.6	6.08		4.14	8	7.01	9.58
Lack of access to the technology	4.97	4.70	5.53	4.84	3.14	3.55	6.88	5.85	8.78
Lack of skilled personnel	8.38	7.48	*10.17*	9.33		4.52	8.98	8.39	*10.05*
Leakage of hazardous material			8.23		4.19		5.15		
Low consumer demand and acceptance	8.62	8.98	*10.53*	9.04	5.21	5.28	9.33	8.32	9.36
Low product and performance reliability	8.17	7.69	7.37	8.33	4.97	6.06	8.87	9.14	9.78
Misplaced incentives	7.74	7.25	9.03	6.84	5.92	5.02	*11.58*	*10.56*	*10.09*
Noise and building vibration									*10.87*
Operational failure	8.86	8.48	8.83	7.76	6.4	7.29	8.18	8.3	9.62
Physical degradation							8.8	8.77	
Presence of system constraints	*10.78*	8.94	*10.83*	*10.24*	5.24	5.42	*10.53*	*10.58*	*11.25*
Slow response rate to temperature changes			*10.19*						
Surface condensation and mould growth	*10.14*	7.75	8.73	7.73					
Unauthorized building entrance		6.06							
Uncertain availability of incentives	7.97	6.85	7.9	7.29			*14.08*	*13.85*	*11.89*
Uncertain government policies							*14.35*	*13.85*	*12.13*
Uncertain payback period	9.07	8.58	*10.77*	8.51	4.38	5.54	*11.58*	*12.82*	*13.09*

From Table 4-4 we can see that critical risks were found in six out of the nine technologies and these technologies were related to three out of the four main categories HVAC, solar, and wind. None of the lighting technologies were found to be critically influenced by any critical risk. This may indicate the maturity of these technologies and their successful application in Australia's green office buildings compared to the other EERTs. Similarly, no critical risks were identified for night purge and natural ventilation in the HVAC category.

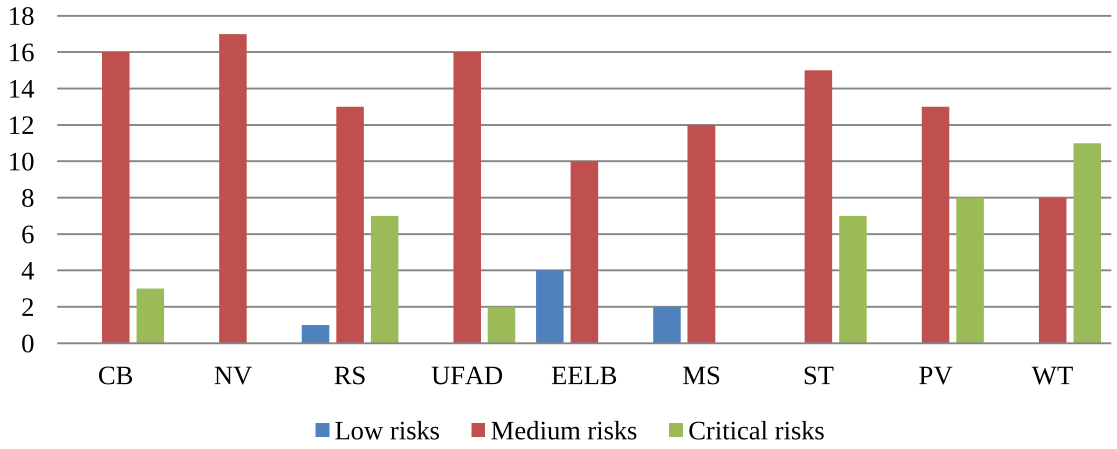

Figure 4-5: Number of risks affecting each EERT according to the level of risk impact

From Table 4-4 and Figure 4-5 it is clear that the majority of EERTs are most affected by risks classified by industry practitioners as medium level. This indicates that industry practitioners are generally cautious about EERT application. Only energy efficient light bulbs, motion sensors, and radiant systems were subject to low level risks. Night purge and natural ventilation was the only EERT with all of its risks being evaluated as medium. As previously mentioned, six technologies were considered subject to critical risks: chilled beams, radiant systems, underfloor air distribution, solar thermal systems, photovoltaic panels, and wind turbines. The only EERT that had a number of critical risks outweighing medium risks is wind turbines. This indicates that industry practitioners in Australia are not confident with wind turbine implementation and its use at this stage is not recommended due to its critical risk profile.

In general, the majority of the critical risks identified were applicable to renewable energy technologies. In particular, wind turbines were considered subject to most critical risks. In contrast, underfloor air distribution and chilled beams had the fewest identified critical risks of the six different technologies. This indicates that industry practitioners see renewable energy technologies as a risky investment compared to energy efficient technologies. Unlike energy efficient technologies, renewable energy technologies share a number of critical risks indicating that these technologies are not fully prepared for implementation in the Australian market and that more in-depth investigations should be carried out to find methods to manage these risks.

Lack of access to funds and *presence of technical constraints* were risks shared by the energy efficient technologies. This shows that these technologies are mainly subjected to financial and technical issues. Renewable energy technologies, on the other hand shared seven critical risks: e*mergence of new, superior technology, lack of access to funds, misplaced incentives, presence of system constraints, uncertain availability of incentives, uncertain government policies,* and *uncertain payback period.* These risks cover financial, market, political and technical issues, indicating that the application of renewable energy technologies represents a major concern in the green building market.

Future change in regional climate and weather fluctuation was found to be critical for photovoltaic panels and wind turbines and not for solar thermal systems, possibly due to the fact that both photovoltaic panels and wind turbines produce electricity, whereas solar thermal systems produce heat. The impact of the loss or shortage of electricity is greater than that of the loss or shortage of heat as a result of climate change or weather fluctuations.

Lack of access to funds and *presence of system constraints* were identified as critical for all six technologies. Despite the Australian government measures to resolve the issue of funding for green buildings, for example by establishing a Green Building Fund, industry practitioners remain concerned with the funding issue. The *presence of system constraints* usually reflects limitations in the use of a certain technology, and this indicates that these technologies have not yet reached a mature level of operation. Thus, more in-depth approaches to the management of these critical risks should be explored.

The critical risk with the highest mean risk impact value was *uncertain governmental policies.* This might denote that the majority of green industry practitioners are not confident with government policies or the way these policies are formulated. At the same time, they are concerned with the consequence of these uncertainties. This could also explain the high mean risk impact value for *uncertain availability of incentives* which represent a significant feature of government policies.

4.5.2 Part two: Exploration of practitioners risk perception

An ANOVA test was used to compare views among the four main stakeholder groups. The analysis provided the opportunity to identify those risks which showed significant differences in the opinions of the stakeholder groups with regard to risk impact. Hence, the industry practitioners with the highest concerns for EERTs risks and the practitioners with the lowest concerns on EERTs risks could be identified. A post-hoc test was used to examine in details the differences identified. Only risks where stakeholders had significant differences in opinion at $p<0.05$ are discussed. Table 4-5 summarizes the findings of the analysis with significance level of $p<0.05$.

Table 4-5: Comparison of stakeholders risk perception

Technology	Risk	Stakeholder with higher risk perception (A)	Stakeholder with lower risk perception (B)	Mean Difference (A - B)	Significance
CB	Emergence of new, superior technology	Architect	Engineer	5.686	0.002
NV	Uncertain payback period	Engineer	Architect	4.442	0.028
	Low consumer demand and acceptance	Project Manager	Architect	7.642	0.012
PV	Uncertain payback period	Contractor	Project Manager	8.306	0.006
	Hidden costs	Contractor	Project Manager	6.014	0.038
	Lack of access to information about technology	Contractor	Engineer	6.567	0.003
	Lack of skilled personnel	Project Manager	Engineer	2.964	0.042
	Lack of access to the technology	Contractor	Architect	5.611	0.018
		Contractor	Engineer	5.290	0.017
	Emergence of new, superior technology	Project Manager	Engineer	5.268	0.018
	Physical degradation	Contractor	Architect	5.222	0.039
		Contractor	Project Manager	5.375	0.037
RS	Misplaced incentives	Contractor	Architect	9.524	0.036
		Contractor	Engineer	10.137	0.011
ST	Emergence of new, superior technology	Contractor	Engineer	8.461	0.006
UFAD	Lack of access spare parts	Engineer	Contractor	2.985	0.012
		Project Manager	Contractor	6.436	0.017
	Emergence of new, superior technology	Architect	Engineer	4.722	0.035
WT	Lack of skilled personnel	Contractor	Engineer	7.357	0.039
		Contractor	Architect	7.850	0.036

Major differences in relation to risk perception are highlighted in Table 4-5. It is clear that all EERTs, with the exception of lighting technologies, are subject to major different levels of risk perception among particular stakeholder groups. Along with the fact that no critical risk was identified for lighting technologies in Part one of this analysis, this finding further confirms that the application of lighting technologies will not impose critical risks for project stakeholders, based on the views of the industry practitioners who responded to the questionnaire.

Emergence of new superior technology had significant levels of differences in risk perception among industry partitioners in four technologies: chilled beams, photovoltaic panels, solar thermal systems, and underfloor air distribution. Architects, project managers, and contractors were found to be more concerned with this risk than engineers. This may be due to the fact that engineers most often have the opportunity to select the EERTs to be implemented in green buildings. Therefore, they are confident of their selection of the technology and less worried about new superior technologies emerging. On the other hand, other industry practitioners are more concerned, because they will have to deal with design alterations and site preparation if such a risk occurs.

Generally, contractors showed higher risk perceptions than other industry practitioners in all renewable energy technologies, especially photovoltaic panels, where contractors demonstrated higher risk perceptions for seven risks. This may be due to the fact that contractors are responsible for transferring design ideas from paper into reality, but they may not be well equipped with sufficient knowledge and information about these technologies.

4.5.3 Part three: Affected stakeholders

For all 30 risks, an assessment was made to examine which stakeholders were affected by each risk as well as the rank of impact among the affected group. The stakeholders included architects, engineers, project managers, suppliers, occupiers and owners. Interests of each stakeholder group in the implementation of EERTs in green office buildings are expressed in Table 4-6. The Chi-square test was selected for the analysis.

Table 4-6: Stakeholder interst in green office building EERTs

Stakeholder	Interest in green office building EERTs
Architects	Overall aesthetic view of the building and EERTs
Engineers	Success of design and operation of the building and EERTs
Project managers	Delivery, planning, and execution of the building and EERTs
Suppliers	Profits through sales of quality materials and technologies
Occupiers	A building that is environmentally friendly with healthy space
Owners	Successful implementation of the building and EERTs throughout the lifecycle

After running the test on all 30 risks, selections of the affected stakeholders were made based on the standardized adjusted residual (SAR) value. Whenever the value of SAR lay outside ±1.96 it was considered to be significant at $p<0.05$ (Field, 2009). For each risk the participants were asked to place a tick for every stakeholder they believed would be affected by the risk. In the Chi-square test analysis the comparison was undertaken between *Yes* for affected by the risk and *No* for not affected by the risk. Table 4-7 illustrates the SAR values for *Yes* answers, which represents the affected stakeholders. Appendix 4 presents the full analysis results.

Table 4-7: Stakeholders affected by EERTs risks

Risk	SAR value						
	Architect	Engineer	Project Manager	Supplier	Contractor	Occupier	Owner
Aesthetically unpleasing	9.8					6.5	7.6
Bird collision						6.8	7.8
CO_2 suffocation						8.7	4.9
Dangerous emissions from unit production						6.6	4.7
Draught & thermal discomfort						10.9	3.8
Emergence of new and superior technology		3.1					7.2
Fire risk						6.7	7.8
Future change in regional climate and weather fluctuation		3.6				4.7	6.3
Glare risk from collector sunlight reflection						8.7	5.7
Headaches and skin rash						12.5	5.1
Hidden costs							13.5
Lack of access to funds							15.1
Lack of access to information about technology	4.3	8.8					
Lack of access spare parts					6.1		7
Lack of access to the technology		4.3			3		
Lack of skilled personnel			2.4		9.8		
Leakage of hazardous material						7.1	6
Low consumer demand and acceptance				2.4			5.1
Low product and performance reliability						4.5	8.1
Misplaced incentives							12.7
Noise & building vibration						8.8	6
Operational failure					2.8	6.1	7.8
Physical degradation						3.1	9.8
Presence of system constraints		7.1					
Slow response to temperature changes						10.2	4.7
Surface condensation and mould growth						7.5	7.3
Unauthorized building entrance						9.1	6.9
Uncertain availability of incentives							15.2
Uncertain government policies							11.2
Uncertain payback period							16

Overall, Table 4-7 shows that the stakeholders most affected by EERT risks are the owners, followed by the occupants, and the least affected stakeholders are the project managers and EERT suppliers. Owners will be affected by all sorts of financial, political, market, technical, and environmental risks, while occupants will be affected by risks during the occupancy period of the building, with the majority of risks occurring during the operation of the EERTs.

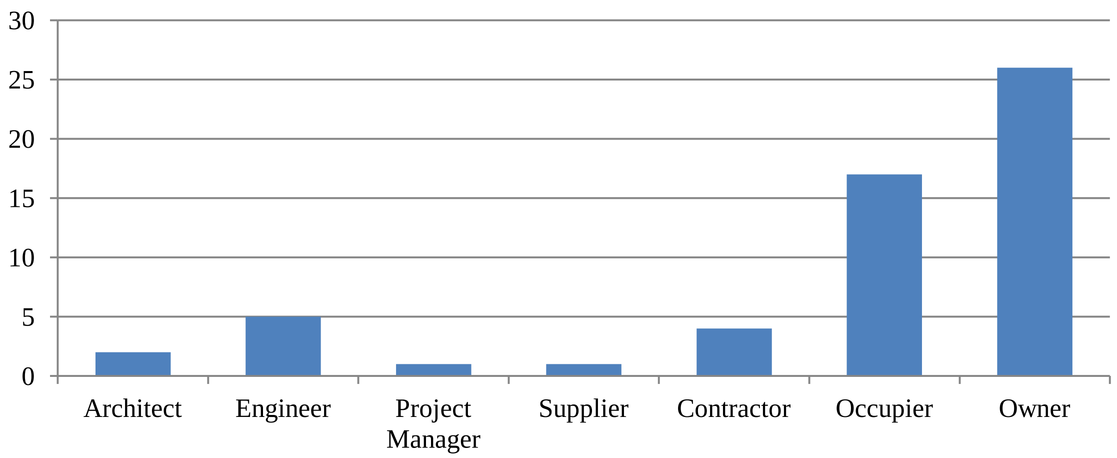

Figure 4-6: Stakeholders and the number of risks they are affected by

According to Figure 4-6, owners appear to be the stakeholders most affected by the majority of EERT risks, being considered to be affected in 26 of the 30 risks. This raises the matter of high exposure of owners to EERT risks and the need for management strategies. Occupiers follow owners in the number or risks they are affected by, with 17 of the 30 risks. The other EERT stakeholders, including architects, engineers, project managers, suppliers, and contractors were considered to be affected by a limited number of risks. For instance, architects, engineers, and contractors were identified by industry practitioners to be affected by two, five and four risks respectively. This is insignificant when compared to the number of risks that affect owners and occupants. On the other hand, project managers and suppliers were each identified to be affected by only one risk. Thus, these two industry practitioner groups are in general the safest from EERT risks.

Lack of access to information and the *presence of system constraints* in EERTs are the two risks by which engineers are most affected. Engineers should have access to EERT information in order to select the most appropriate technology for a green building, and the presence of system constraints can influence the integration of new technology with the current building service systems. Hence, the lack of information will cause engineers to produce faulty designs. Other risks that have an effect on engineers include *lack of access to the technology*, *emergence of new superior technology*, *future change in regional climate and weather fluctuation*. Engineers have a significant role in selecting the EERTs for buildings which requires them to take responsibility and hence makes them more vulnerable to these risks. The difficulty of obtaining access to EERTs can cause issues and might increase costs or delay project schedules, even though the most suitable technology was selected. The sudden emergence of a superior technology with enhanced performance might be frustrating to the owners who might have lost the chance to acquire a better option due to the lack of market awareness by the engineer. Climate change and weather fluctuation can also affect the engineer's technology selection or design. This can happen due to bad modelling or the use of insufficient data. In some cases, a change in weather patterns can cause the technology to become obsolete.

Contractors are affected by risks such as *lack of skilled personnel*, *lack of access to the technology*, *lack of access to spare parts*, and *operational failure*. All these risks reflect the reality that contractors lack human and material resources for green building technology work. They need urgent training and access to information and materials in order to complete their work with good workmanship. For instance, a lack of skilled personnel will cause job complications, especially with EERTs which require particular skills for installation and commissioning.

Similar to engineers, architects are also affected by the risk of *lack of access to information* about EERTs as it is vital for them to have sufficient information on the technology. Architects are most affected by the occurrence of *aesthetically unpleasing* appearance, as this plays a major role in their job.

Like contractors, project managers are also affected by the risk of *lack of skilled personnel*. This is because not having the knowledgeable and skilled personnel in the area of green buildings in the team might lead to an increase in the number of risks, which in turn can significantly affect project progress.

Finally, suppliers are affected by the risk of *low consumer demand and acceptance*, simply because, if the demand for and public acceptance of EERTs reduces, their businesses will be considerably affected.

4.5.4 Part four: Likely lifecycle stages of risk occurrence

This section investigates the likely lifecycle stages of occurrence for the 30 risks of EERTs, including the identification of likely lifecycle stages of occurrence and the rank of occurrence of these lifecycle stages. For this part, the method used for data analysis was similar to that used in Part three. Industry practitioners were asked to select the lifecycle stage at which they suspect the risk will likely occur. The lifecycle stages included six stages: technology manufacturing, building concept, building design, building construction and technology installation, operation and maintenance, and demolition and recycling. A total of 29 risks were evaluated, as the risk of *dangerous emissions from unit production* was not considered because the stage at which this risk might occur was clear from the name.

In the Chi-square analysis a comparison was undertaken between *Yes* for risk occurring in that lifecycle stage and *No* for risk not occurring in that lifecycle stage. Table 4-8 illustrates the SAR values for *Yes* answers, which represent the lifecycle stages at which these risks are likely to occur. Appendix 5 presents the full analysis results.

Table 4-8: Technology or building lifecycle stages at which EERTs risks might occur

Risk	SAR value					
	Manufacturing	Concept	Design	Constriction	Operation	Demolition
Aesthetically unpleasing		5.6	7.5			
Bird collision					12.6	
CO_2 suffocation					12.6	
Draught & thermal discomfort					12.1	
Emergence of new and superior technology						
Fire risk					11	
Future change in regional climate and whether fluctuation					7.4	
Glare risk from collector sunlight reflection					9.4	
Headaches and skin rash					12.9	
Hidden costs				5.7	6.6	
Lack of access to funds		7.5	3.5			
Lack of access to information about technology		3.5	7.6			
Lack of access to spare parts					13.4	
Lack of access to the technology	2.6	2.2	3.3			
Lack of skilled personnel				8.5	5	
Leakage of hazardous material					9.8	
Low consumer demand and acceptance		5.5	2.3			
Low product and performance reliability					13.2	
Misplaced incentives		3.6				
Noise & building vibration					10.8	
Operational failure					16.8	
Physical degradation					13.1	
Presence of system constraints		2.8	8.2			
Slow response rate to temperature changes					10.7	
Surface condensation and mould growth					12.3	
Unauthorized building entrance					12.8	
Uncertain availability of incentives		2.7			2.2	
Uncertain government policies		2.8				
Uncertain payback period		4.5	3.1		3.4	

Table 4-8 captures the relationships between the risks associated with EERTs and the lifecycle stages of the technology or the building when these risks will likely occur. The operation stage of the building and the technology seem to be the most critical stage for EERTs, as the majority of risks might occur at this stage.

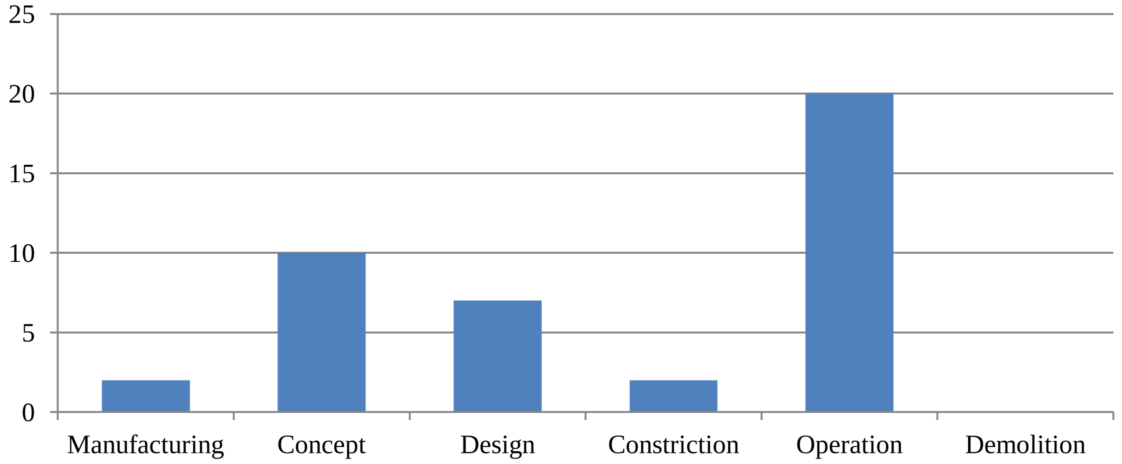

Figure 4-7: The number of risks and the lifecycle stages of occurrence

From Table 4-8 and Figure 4-7 it is clear that the lifecycle stage at which the majority of risks are most likely to occur is the operation stage. Industry practitioners identified 20 out of the 30 risks as occurring at this stage. EERTs are active at this stage and any issues that were not resolved during the previous lifecycle stages will become visible. This makes the operation stage a crucial stage for EERT implementation in Australian green office buildings. Hence, focus should be directed to this stage in any risk management activity. The second stage at which EERT risks are likely to occur is the concept stage, with 10 risks identified by industry practitioners as being likely to occur in it. This is due to the fact that during this stage everything is still on paper and any unclear or ignored issues will become a future risk if not resolved quickly. The design stage comes in third position with the number of risks occurring in it. This stage is very much related to the previous concept stage which explains the similar number of risks occurring in the two stages. Industry practitioners identified seven risks as occurring frequently during this stage. If issues were not resolved during design, complications will appear at later stages of the technology's or the building's lifecycle. According to the opinion of the industry practitioners, two stages, technology manufacturing and building construction and technology installation both had two risks likely to occur in them. This reflects the moderate level of significance for these two stages in terms of EERT risks. The only lifecycle stage where no risks were pinpointed to occur was the building demolition and technology recycling stage, probably because the number of risks that could occur at that stage were insufficient. More research should be conducted in this area.

Hidden costs and *lack of skilled personnel* are the two risks associated with EERTs that are likely to occur during the construction and technology installation stage. Clearly, hidden costs occur during this stage when EERTs are placed into practice and any unidentified or resolved issues from the previous lifecycle stages will be costly and might even lead to failure in the worst-case scenario. Similarly, skilled and knowledgeable personnel are most needed during this lifecycle stage and their absence can lead to implementation failure of EERTs.

Lack of access to the technology was considered to occur during the technology manufacturing stage. This could refer to the difficulty for manufacturers in obtaining access to the equipments or materials necessary for the production of EERTs, either because the costs are high or because they are imported from overseas and may be exposed to delays and other issues affecting their production.

Emergence of new superior technology was not identified to occur during any stages. This is because the industry practitioners believed that new superior technologies might be introduced at any stage of either the technology or building lifecycle and that it is a matter of innovation.

The risk of *uncertain availability of incentives* was identified by the industry practitioners to occur during the concept and operation stages with an SAR value higher for the concept stage indicating higher possibility of occurrence in that stage. Incentives are offered by the government to those who are seeking to purchase certain EERTs as a way to promote these technologies, which explains the highly possibility for this risk during the concept stage. However, the occurrence of this risk in the operation stage after the purchase of the technology and its operation relates to other types of incentives which are indirect, such as utility prices. For instance, it is well known that utility prices increase with time, making the possession of an EERT like photovoltaic panels an opportunity for savings, but if extra subsidies were offered to support or lower utility prices, savings for EERTs would reduce and their attractiveness decrease.

4.6 Findings of Questionnaire Data Analysis

Several findings can be provided based on the opinions of industry practitioners including the four main groups: architects, contractors, engineers, and project managers, provided in the questionnaire. As the data analysis for the questionnaire was presented in four parts, the findings of each part will be presented under the same headings. The findings were subsequently used for the preparation of the interview questions. Furthermore, significant findings were used as the basis for developing the critical risk management framework for EERTs implemented in Australian green office buildings.

4.6.1 Identification of critical risks

Several findings can be drawn from the results of Part one of the questionnaire as follows:

- The number of risks identified to be critical by the industry practitioners is 14.
- Industry practitioners evaluated eight of the EERTs considered in this study to be most subject to medium risks. This indicates their cautious view of the application of EERTs.
- The EERT subject to the majority of critical risks was wind turbines. Thus, industry practitioners believe this EERT to be immature in the context of implementation in Australia.
- None of the lighting technologies were considered subject to critical risks. Therefore, the use of energy efficient light bulbs and motion sensors is considered the safest in terms of level of risk compared to the other EERTs, and their wide usage should be promoted.
- Most critical risks identified from the analysis were found to be applicable to renewable energy technologies. Consequently, industry practitioners generally see renewable energy technologies as more risky than energy efficient technologies. At the same time, renewable energy technologies share most of the critical risks which supports their being a risky investment and the need for a comprehensive risk management plan for these technologies.
- Two critical risks, l*ack of access to funds* and *presence of system constraints,* were identified to be subject to all six EERTs with critical risks. By this industry practitioners are indicating that there is still a need for more means of funding EERTs and those current policies are not sufficient. There respondents are also indicating that these EERTs are coupled with constraints that may limit their potential.

- The critical risk of *uncertain government policies* was found to have the highest mean risk impact value. Industry practitioners evaluated this risk to be their highest concern with respect to renewable energy technologies, indicating their lack of confidence in government policies or the way these policies are formulated. The critical risk with the second highest mean risk impact value is *uncertain availability of incentives*. These incentives are also linked to government policies, which explain the high risk impact value. Similarly to *uncertain government policies*, industry practitioners are not confident of or satisfied with the incentives offered for EERTs.

4.6.2 Exploration of practitioners' risk perceptions

A number of findings can be drawn from the results of Part two of the questionnaire. Following are the significant findings from the exploration of practitioners' risk perceptions:

- Major different levels of risk perception among stakeholder groups were found in all EERTs, with the exception of lighting technologies. This further confirms that the application of lighting technologies will not impose high risks for project stakeholders, based on the views of the industry practitioners who responded.
- Across the different EERTs the critical risk of e*mergence of new superior technology* was rated more highly by architects, contractors and project managers than engineers. This is because engineers are mainly responsible for EERT selection and integration into buildings, whereas the other industry practitioner groups are responsible for any design alteration or site preparation necessary.
- Overall, contractors showed greater perception of the EERTs risks of renewable energy technologies, specifically photovoltaic panels. Contractors are responsible

for transferring design ideas from paper into reality and this may result in them dealing with many risks. This explains their higher risk perceptions compared to other industry practitioners.

4.6.3 Affected stakeholders

Following are the significant findings on the affected stakeholders:

- The stakeholders most affected by EERT risks are the owners, followed by the occupiers.
- The stakeholders least affected by EERT risks are the project managers and suppliers.
- Engineers are affected by several risks of EERTs with *lack of access to information* and the *presence of system constraints* being the two main risks. In order for an engineer to select the appropriate EERTs for a building, sufficient knowledge and information on the EERTs must be available. Otherwise severe consequences may follow. System constraints can also affect engineers if EERT limitations are not considered or identified in the selection process.
- Contractors were identified to be affected by a number of risks including *lack of skilled personnel*, *lack of access to the technology*, *lack of access to spare parts,* and *operational failure*. These risks represent several issues that contractors face in their daily work and can affect their performance.
- Architects were identified as being affected by two risks: *lack of access to information* and *aesthetically unpleasing*. Similarly to engineers, sufficient knowledge and information on EERTs is vital for architects. As visual appearance plays a significant role in architects' jobs, any risks that influence this element will affect architects.

- Project managers were found to be affected by the risk *lack of skilled personnel*. Not having skilled personnel on-site might have serious consequences for the project's progress and can accordingly affect the project manager.
- Suppliers were found to be mainly affected by the risk of *low consumer demand and acceptance*. Lower demand for EERTs will affect the suppliers business and can lead to closure or change of products.

4.6.4 Likely lifecycle stages of risk occurrence

Following are the significant findings for the likely lifecycle stages of risk occurrence:

- Most risks are likely to occur during the operation stage. Because EERTs are created to achieve their purpose at this stage of the lifecycle.
- The second stage in terms of risk is the concept stage, basically because during this stage many ideas are proposed and if not studied carefully might cause risks in future stages of the lifecycle.
- The design stage comes third for risks occurrence. Ideas are placed on paper in this stage and mistakes can affect future lifecycle stages.
- According to the opinions of industry practitioners, two risks are likely to occur in the two stages, technology manufacturing and building construction and technology installation. Thus, attention should be given to these lifecycle stages in terms of risk management.
- The demolition and recycling stage was identified as the only lifecycle stage with no risks likely to occur in it, making it the safest lifecycle stage in terms of EERT risk occurrence.

- Only one risk was not identified as occurring at any of the lifecycle stages, which is e*mergence of new superior technology*. This is due to the fact that new superior technologies can be introduced at any time.
- The risk of *uncertain availability of incentives* was identified by industry practitioners as being likely to occur in both the concept and operation stages. This is because the investigation of available incentives is usually done in the concept stage and uncertainty of incentives can have a negative impact on EERT implementation. In the operation stage, indirect incentives such as utility prices are considered and any uncertainty in them can also affect the implementation of EERTs.

4.6.5 General findings

It can be seen in Tables 4-4 that the *emergence of new superior technology* is a critical risk for more than one technology. Table 4-5 shows that engineers' perceptions of the significance of this risk were much lower than other industry practitioner groups. However, Table 4-7 indicates that engineers are one of the stakeholder groups most affected by this critical risk. Therefore, engineers should give more attention to this critical risk in order to avoid or at least reduce the level of risk impact on them.

Furthermore, in Tables 4-4, 4-5, and 4-7 the *lack of skilled personnel* was identified as critical for more than one technology. Project managers and contractors perceived this critical risk as being higher than engineers and both groups were identified as being affected by this critical risk. Hence, more attention should be given to these two groups of EERT stakeholders in order to manage this critical risk successfully.

CHAPTER 5: INTERVIEW DATA ANALYSIS AND FINDINGS

5.1 Introduction

The findings of the questionnaire analysis detailed in Chapter 4 revealed that EERTs implemented in Australian green office buildings are potentially subject to 14 critical risks. The chapter also identified the stakeholders affected by the risks of EERTs and the likely lifecycle stages of risk occurrence. These critical risks may influence the implementation of these EERTs and their spread in Australian green office buildings. Action must therefore be taken in order to manage those risks evaluated as critical by different groups of industry practitioners.

In this chapter, the semi-structured interviews are discussed. The results were will e used to find methods to manage the critical risks of EERTs identified in Chapter Four. Once again a sample of industry practitioners was approached to take part in the holistic management process. The chapter sets out the purpose of the interviews, the participants' profile, the data analysis, and the findings.

5.2 Purposes of Interview

The interview survey was conducted to meet the following objectives:

- Understand and recognize the causes of the critical risks of EERTs,
- Understand and recognize the impacts of the critical risks of EERTs,
- Identify measures to manage the critical risks of EERTs,

- Identify the stakeholders to manage the critical risks of EERTs,
- Identify the lifecycle stages of action to manage the critical risks of EERTs.

5.3 Sample Profile

A total of 20 professionals participated in 20 individual interviews conducted in November and December 2010 and February and March 2011. All interviews took place in Melbourne, Victoria. The interviewees were selected either based on their indication of willingness to participate in the interview when answering the questionnaire survey or by recommendation. Industry practitioners from different backgrounds were selected to provide a comprehensive range of answers. Four main groups of industry practitioners were targeted: architects, contractors, engineers, and project managers, and 19 of the 20 participants were Green Star Accredited Professionals certified by the Green Building Council of Australia Figure 5-1 illustrates the interview participants' profile.

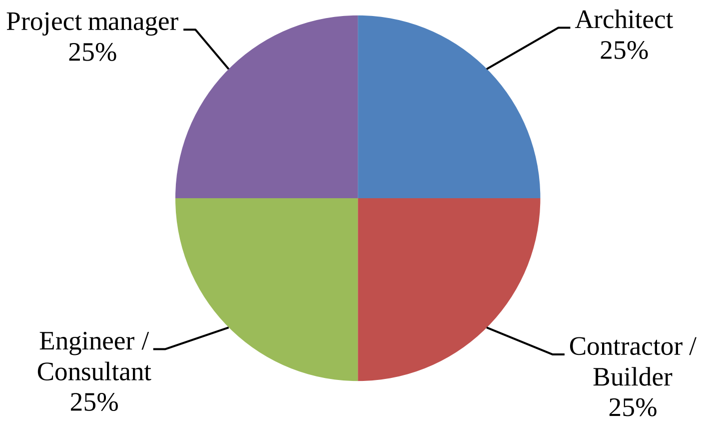

Figure 5-1: Participants' profile

The industry practitioners involved in the semi-structured interviews included five architects, five contractors, five engineers, and five project managers. As shown in Figure

5-1, each group represents 25% of the sample size. All participants were knowledgeable about and had had experience with EERTs.

5.4 Interview Data Analysis

The data collected from the semi-structured interviews were analysed to achieve the five objectives outlined in Section 5.2. The following analysis is divided into five parts with each part representing the analysis for one of the interview objectives.

Part one of the data analysis discusses the causes of the critical risks of EERTs implemented in Australian green office buildings. Industry practitioners were asked to give the causes of these critical risks. The causes will assist stakeholders to know the triggers of the critical risks of EERTs and hence avoid them and or put precautions in place.

Part two of the data analysis covers the impacts of the critical risks of EERTs implemented in Australian green office buildings. The interviewees provided feedback on the impacts of these critical risks. Knowledge of the impacts will help stakeholders have a sense of the possible damage from these critical risks and as a result take them into consideration.

Part three of the data analysis presents the measures to manage the critical risks of EERTs implemented in Australian green office buildings. The industry practitioners interviewed provided feedback on the measures that can be used to mitigate these critical risks. This will allow stakeholders to take action against critical risks and have informed advice on what to do from professionals in the field.

Part four of the data analysis covers the identification of the stakeholders to manage the critical risks of EERTs implemented in Australian green office buildings. The interviewees selected the stakeholders that they believe are able to manage each of the critical risks. This will give stakeholders the chance to know who is able to manage the critical risks of EERTs in a professional and efficient manner, based on the opinion of experienced industry practitioners.

Part five of the data analysis covers the identification of the lifecycle stages to take action in response to the critical risks of EERTs implemented in Australian green office buildings. The industry practitioners interviewed selected what they believe are the most appropriate lifecycle stages for action against the critical risks of EERTs. By knowing the best time to act, stakeholders will be able to take action at the right time and reduce or eliminate the critical risks.

Prior to the start of each interview, participants were asked to select the risks they believed to be critical from a list that included the 14 critical risks deriving from the questionnaire data analysis results. See Chapter 4 for details. After they made their selection, they were then asked to comment on those they saw as critical in terms of causes, impacts, managing measures, managing stakeholders, and lifecycle stages of action. Table 5-1 illustrates the critical risks and the number of industry practitioners who believe that they are critical.

Table 5-1: Critical risks and the number of industry practitioners that believe as critical

Critical risks	Number of industry practitioners see as critical
Emergence of new and superior technology	13
Future change in regional climate and whether fluctuation	10
Hidden costs	15
Lack of access to funds	10
Lack of skilled personnel	14
Low consumer demand and acceptance	9
Misplaced incentives	12
Noise & building vibration	8
Presence of system constraints	14
Slow response rate to temperature changes	9
Surface condensation and mould growth	8
Uncertain availability of incentives	11
Uncertain government policies	17
Uncertain payback period	15

From Table 5-1 it is clear that most of the interviewees (85%) agree that *uncertain government policies* pose a critical risk. On the other hand, critical risks such as *low consumer demand and acceptance*, *noise & building vibration*, *slow response rate to temperature changes*, and *surface condensation and mould growth* were rated by at least 40% of the industry practitioners as critical risks. This could be because three out of the four critical risks relate to certain categories of EERTs and not all industry practitioners are aware of them. Thus, only those industry practitioners with experience in these EERTs provided their judgement. The rest of the critical risks are seen as critical by at least 50% of the industry practitioners interviewed which validates their significance.

5.4.1 Causes of critical risks

The interviewees were asked to provide the causes of the 14 critical risks identified from the questionnaire. In total, they proposed 37 different causes for EERT critical risks. Table 5-2 lists the causes of EERT critical risks according to their categories and Table 5-3 lists the causes of EERTs and their corresponding codes. Causes of EERT critical risks and interviewees' opinions are discussed in this section.

Table 5-2: Causes of EERTs critical risks

Code	Causes of the critical risks of EERTs	Abridged names
C1	The introduction of new more effective EERTs at a fast pace making previous versions redundant.	Fast introduction of new EERTs
C2	Market forces and innovation.	Market forces
C3	Suppliers and contractors increasing their costs as soon as they know that potential owners of EERTs are seeking them for reasons apart from financial costs.	Speculative increase of costs
C4	Clients and developers mostly concerned with financial aspects of EERTs and not considering other aspects such as environment, marketing and quality.	Financial aspects concern
C5	Not recognizing EERTs' cost at early stages of project.	Cost uncertainty at early stage
C6	High capital cost.	High capital cost
C7	Limited number of projects incorporating EERTs.	Limited EERT projects
C8	Insufficient financial incentives for industry practitioners to become skilled with EERTs.	Insufficient financial incentives
C9	Companies' failure to provide sufficient support to invest in staff training.	Insufficient staff training
C10	Lack of information and awareness among EERT stakeholders.	Lack of stakeholder awareness
C11	Existence of different schemes, models, and tools for green building accreditation.	Various accreditation schemes
C12	Uncertainty in the prediction of future electricity and water prices.	Utility price uncertainty
C13	Industry practitioners do not have a holistic view, as most practitioners are only knowledgeable in their own field of practice.	Lack of skills in technology integration
C14	The design of EERTs specifically for certain climate profiles, leading to difficulties for these technologies to react to weather fluctuation and climate change.	Design for certain climate
C15	New technologies in general have less capacity and fewer safety factors in design compared to old technologies making them more susceptible to weather fluctuation and climate change.	Limited technological tolerance to weather
C16	Professionals selecting EERTs not considering sufficient timeframes for weather cycles.	Insufficient design for weather
C17	Lack of knowledge, education and training among industry practitioners.	Industry practitioners' lack of knowledge
C18	Poorly specified projects and unsuitable contract conditions.	Poorly specified projects
C19	The selection of unqualified people for jobs involving EERTs.	Selection of unqualified people
C20	Personnel on the top of the pyramid are well educated on EERTs but the issue affects personnel on the bottom of the pyramid.	Unqualified frontline workforce
C21	Developers installing EERTs in order to acquire a green building rating without taking into account the soundness or quality of these technologies.	Developers targeting star rating only
C22	Unproven technology.	Unproven technology
C23	System limitation.	System limitation

Table 5-2 (*continued*): Causes of EERTs critical risks

Code	Causes of the critical risks of EERTs	Abridged names
C24	Being one of first adopters without having sufficient experience.	First adopters
C25	Green building council, suppliers and people promoting the use of EERTs providing the public with incorrect information.	Incorrect information from professionals
C26	Developers or clients not interested to invest in technologies that do not have instant results, especially when the developer or owner does not have to deal with ongoing costs.	Unbalanced incentives on responsibility and benefits
C27	Consulting industry in Australia very risk-averse.	Risk-averse industry
C28	Resistance to change.	Resistance to change
C29	Government not dedicating sufficient time to policies related to EERTs and sightlessness.	Government sightlessness
C30	Government not offering the right economic incentives for EERTs and being cautious in providing funding.	Incorrect economic incentives
C31	Constant policy changes and no clear goals.	Constant policy changes
C32	Stakeholders not being aware of accessible incentives or how to claim them.	Unawareness of incentives
C33	Government lacking understanding and exposure to EERTs.	Government lack of exposure
C34	Government not taking climate change seriously.	Unserious attitude towards climate change
C35	Taxes imposed by government increasing costs of EERTs.	Increasing costs due to taxes
C36	The unpredictability of weather.	Unpredictability of weather
C37	Poor occupant behaviour.	Poor occupant behaviour

Table 5-3: EERTs critical risks and their causes by code

Critical risks	Causes code
Emergence of new and superior technology	C1, C2, C10
Future change in regional climate and weather fluctuation	C14, C15, C16, C36
Hidden costs	C3, C17, C18, C24, C25
Lack of access to funds	C4, C5, C6, C10, C26, C30
Lack of skilled personnel	C7, C8, C9, C10, C19, C20, C27, C28, C31
Low consumer demand and acceptance	C6, C10, C22, C28
Misplaced incentives	C4, C21
Noise and building vibration	C17, C23
Presence of system constraints	C13, C17, C22
Slow response rate to temperature changes	C23
Surface condensation and mould growth	C14, C23, C37
Uncertain availability of incentives	C29, C30, C31, C32
Uncertain government policies	C11, C29, C31, C33, C34
Uncertain payback period	C4, C6, C12, C22, C31, C35

As the above table shows, the industry practitioners interviewed suggested that C1 and C2 are causes of the critical risk *emergence of new and superior technology*. They believe that once EERTs are introduced into the market at a rapid rate, people will start to delay purchasing or lose confidence in the industry. Some also related the emergence cause to innovation and the technology revolution. Cause C2 is also related to this critical risk. Some interviewees explained that as demands on EERTs increase, field professionals will work on improving the quality of EERTs, which in turn will lead to their emergence at a quicker rate. The following statements were made by an architect on C1 and a project manager on C2 respectively, when asked to provide causes for *emergence of new and superior technology*:

> *"Because some time you don't put things in, because you know that tomorrow it's going to be out of date (redundant) or the efficiency is improving all the time and you're putting something that won't be efficient. Or you can't be confident of ongoing support and maintenance and also your lack in confidence in whether it's*

the right answer. Because you're hearing that other things come up all the time and you're going to be left with something that is not going to work"

"If the technology keeps coming every few years then people will stop buying. Because you know there is another one around the corner coming"

Another cause revealed by the interviewees is C3 which can trigger the critical risk *hidden costs*. This could happen on purpose by suppliers or builders in order to make more money. In other words, suppliers and builders may not reveal risks to EERT owners and then a risk occurs they will claim more funds to resolve the issue. Furthermore, they may simply provide higher prices to achieve more profits. A project manager made the following comment on C3 when asked about causes of *hidden costs*:

"People who are selling and building these green technologies know that if you want it then you want it for other reasons beside costs so they will increase the costs"

Cause C4 was identified by industry practitioners as triggering three critical risks: *lack of access to funds*, *misplaced incentives*, and *uncertain payback period*. If clients or developers focus only on financial aspects and do not consider other aspects like quality and the environment, access to funds for purchasing EERTs would be difficult. Moreover, EERTs require maintenance which may be costly, but if not carried out as needed, EERT performance may be affected, leading to changes to the payback period. Furthermore, *misplaced incentives* occur when building owners refuse to implement EERTs on their buildings because when the building is occupied by a tenant the owner will not be paying the outgoing costs of energy. Therefore the cost of their installation is an unnecessary expense. The following statement was made by an architect on C4 when asked about causes of *uncertain payback period*:

> *"I think the cause for lack of access to funds is that the value of the equipment is not recognised by the client, they want to see really quick paybacks. Unless it's a financial reward they are not often identifying it for the environmental, sales, marketing, or quality benefits"*

Two causes which are very closely linked are C5 and C6. They were both identified by the interviewees to trigger *lack of access to funds*. C6 was identified to affect two more critical risks: *low consumer demand and acceptance* and *uncertain payback period*. They both relate to *lack of access to funds* because any extra cost to a project might be difficult to gather especially for EERTs because of their high cost and unfamiliarity in most cases. C6 will be a direct reason for the occurrence of *low consumer demand and acceptance* as well as the long payback period. An architect commented as follows on C5 and C6 when asked about causes of *lack of access to funds*:

> *"Because very often these projects costs were not identified early enough and people walk into ESD thinking it could be purchased easily and simply. So, they don't realise that in some cases it cost lots of money"*

The critical risk *lack of availability of skilled personnel* is caused by C7, C8, and C9, according to the interviewees. The limited number of projects involving EERTs means there are limited numbers of skilled personnel capable of dealing with them. At the same time, people will not want to be involved in an industry where no opportunities exist. Furthermore, companies will have no interest in spending time and money training their employees on EERTs if no adequate market is available or high uncertainty exists. The following statements were made by an architect on C7, a project manager on C8, and a contractor on C9 when asked about the causes of *lack of availability of skilled personnel*:

> *"The cause is lack of technological understanding and limited number of projects that contains green technologies"*
>
> *"There are no incentives or initiatives, people don't like the unknown and in stepping in the unknown there is a big risk for any organisation"*
>
> *"I think the reason is that the whole thing is moving fast. Like carbon tax which throws uncertainty at the whole area. Companies don't commit to doing training until there is less uncertainty from higher level. There are a lot of resources but I will say high level uncertainty explains the reason for the presence of unskilled personnel"*

Interviewees identified C10 as the trigger of four critical risks: *emergence of new and superior technology*, *lack of access to funds*, *lack of skilled personnel*, and *low consumer demand and acceptance*. If EERT stakeholders do not have sufficient knowledge of these technologies, they might make wrong decisions on purchasing timing. This might lead them to buy an EERT that is replaced with a better version in days or months. Similarly, the lack of awareness of the stakeholders of EERTs might lead to difficulty in accessing funds due to the inability to justify their need in a project. Moreover, EERT stakeholders may not see the need to hire skilled personnel for a higher cost. Furthermore, consumers will not be interested in EERTs if they are not aware of their potential benefits. The following response on C10 was given by a project manager when asked about the causes of *lack of access to funds*:

> *"The main cause is that people don't understand what they're getting themselves into or its implications. So, they're worried about the money as they're worried*

about the technology and what will it cost them upfront and if it's going to save them money or not"

One of the causes identified by interviewees to trigger the critical risk *uncertain governmental policies* is C11. The participants are annoyed by the existence of several accreditation schemes for green buildings. They claim this increases the complexity of the process and that the government should legislate one comprehensive scheme for green building accreditation. Following is a comment given by a contractor on C11 when asked about the causes of *uncertain governmental policies*:

> *"I think the cause of that risk is inconsistency at the moment. Because there are too many different schemes. In terms of what you can do, you can do green star or NABERS. There are lots of different models and too many different tools that can do pretty much the same thing. Ideally if everything was wrapped into one so if you follow it you will be fine with everything including the building code of Australia"*

Interviewees identified C12 as a trigger for *uncertain payback period*. They believe that an increase in utility prices will increase the benefits of owning EERTs, particularly renewable energy technologies, because the future prices of utilities are uncertain, then subsequently will be the payback period for these technologies. An engineer made the following comment on C12 when asked about causes of *uncertain payback period*:

> *"If the payback is due to energy or water savings then certainly utility prices is the big thing and most people don't know what's going to happen with the prices. They don't know if there is going to be a carbon tax and if there is then what form is it*

going to take and whether it's going to involve the built environment. So, there are lots of unknowns"

According to interviewees, C13 is one of the causes of *presence of system constraints*. They argue that when there is no joint effort between the different practitioners, system constraints will occur. Furthermore, they advise that for a complex project such as green buildings to be called a success, interaction between the different practitioners should occur. When asked about causes of *presence of system constraints* an engineer said the following on C13:

> *"Industry partitioners don't have a holistic overview. Everyone looks into his own interest, for instance HVAC engineers look into their own issues and so on with other industry practitioners. At the end no one identifies technical constraints and it shows up at the end because these people are not working together"*

Two critical risks were identified as being triggered by C14: *future change in regional climate and weather fluctuation* and *surface condensation and mould growth*. Both critical risks are related to weather conditions. The industry practitioners interviewed claimed that some EERTs are designed for certain climates and will not work to full potential if used in different climates, so what works perfectly in Europe might not work in Australia. An engineer made the following statement on C14 when asked about the causes of *future change in regional climate and weather fluctuation*:

> *"The cause of the risk is that some systems and buildings are designed specifically for a certain climate profile and they can't react to changes in climate"*

C15 and C16 are causes identified by interviewees, and are related to *future change in regional climate and weather fluctuation*. The participating practitioners stated that the designs these days of EERTs and new technologies are done with limited tolerance today compared to formerly. Furthermore, a number of practitioners argued that when designers of EERTs did their designs they did not consider sufficient weather data. Therefore, instead of designing EERTs based on the past 10 years of weather cycles, designers should consider the past 50 years of weather cycles. The following comments were made by an engineer on C15, and a project manager on C16 when asked about causes of *future change in regional climate and weather fluctuation*:

> *"Energy efficiency technologies cause the risk! because in the past when we were designing air-conditioning systems for example you did the calculation by hand, you've got a big safety factor on them so that the fluctuation during the days the system was oversized that it could easily handle the changes and get things back into control"*
>
> *"The weather works in a cycle and people haven't seen it, for instance, when water was scarce, the government motivated people to install water tanks and people have done that but now we don't need these water tanks as its raining every second day. So, the scientists are looking on climate change and carbon emissions but they're not looking in long terms and they're not planning right for the future"*

Three critical risks were identified by participating industry practitioners as being triggered by C17: *hidden costs*, *noise and building vibration*, and *presence of system constraints*. To avoid the occurrence of all previously-mentioned critical risks, knowledgeable and well-trained personnel should be involved. Skilled personnel will be able to identify any hidden costs related to EERTs before they occur. In addition, skilled personnel can work together to design and install EERTs without issues of noise or vibration. They can also resolve system constraints in a professional manner. The following statement was made by a project manager on C17 when asked about causes of *presence of system constraints*:

> *"The amount of skills to implement the technology in Australia is lacking compared to Europe, although what we can do in Australia far exceeds what they can do in Europe"*

A number of industry practitioners identified C18 as a trigger for the critical risk *hidden costs*. They believe that current types of contract are not feasible for green buildings and EERTs. In addition, gaps in current contracts allow the hidden costs to occur. The following comment was made by a contractor on C18 when asked about causes of *hidden costs*:

> *"It's probably at the moment poorly specified projects and also contract conditions that aren't really suitable"*

C19 and C20 may trigger the critical risk *lack of skilled personnel*. Some interviewees said that selecting unqualified personnel for a job with EERTs due to their lower costs sends a signal that skilled personnel with experience in the field are not required. This affects the highly qualified personnel in the market. Most of the interviewees also raised the point that for most of the industry, personnel who hold top jobs such as managers and engineers are better educated on EERTs than the frontline workforce who carry out the installation of EERTs. In some cases, the companies are not giving sufficient training for the frontline workforce compared to personnel in higher positions which in turn causes a lack in the skilled personnel. The following statements were made by an architect on C19, and a project manager on C20 when asked about causes of *lack of availability of skilled personnel*:

> *"Lack of right education and not paying the right person and sometime even not wanting to pay more for the right people causes the risk"*
>
> *"I am not sure why but I think the industry is moving very quick and we are not keeping up with the technologies. So, the guys on the top like managers are educated but the guys at the bottom who are doing the work don't know how to handle it!"*

According to the interviewees, C21 is a cause of the critical risk *misplaced incentives*. They claim that many forms of misplaced incentives occur with EERTs and green buildings. One of the major types is the selection by building developers or owners of low-grade EERTs to save costs. This is done to earn as high a green star rating as possible with the lowest possible cost, but it will affect the end user in the long term when these technologies fail or do not work as well as higher quality EERTs. Another type of misplaced incentive in EERTs is also related to green building accreditation, which happens when building developers or owners decide to implement cheap and ineffective EERTs that have similar evaluation points to those with higher prices and better effectiveness. An architect stated the following on C21 when asked about causes of *misplaced incentives*:

> *"The criteria for the evaluation of green buildings are wrong, some technologies which are not effective have similar points to those effective ones and eventually ineffective technologies are used to increase the number of points for the certification. So, at the end developers are looking for getting the biggest number of points with the cheapest technology option"*

Three critical risks are caused by C22 according to the interviewees: *low consumer demand and acceptance*, *presence of system constraints*, and *uncertain payback period*. They respondents claimed that unproven EERTs with limited research and low awareness will have low demand from consumers side. Furthermore, unproven EERTs are not subject to sufficient testing which in turn might cause system constraints. These unproven technologies may also not be reliable, which brings uncertainty to aspects such as the payback period. The following comment on C22 was made by a contractor when asked about causes of *low consumer demand and acceptance*:

> *"High capital cost and not being proven yet as reliable technology"*

Interviewees identified C23 as the trigger of three critical risks: *noise and building vibration*, *slow response rate to temperature changes*, and *surface condensation and mould growth*. These critical risks are related to specific EERTs categorised under wind and HVAC. System limitations can take many forms, including insufficient ventilation and poor humidity or temperature control, and are mainly related to the design of EERTs. The following statement was made by an engineer on C23 when asked about causes of *slow response rate to temperature changes*:

> *"Slow temperature response rate is a system limitation that is an inherent characteristic of radiant heating/cooling systems"*

C24 was identified by interviewees as causing *hidden costs*. They said that because EERTs are relatively new. They have hidden costs and dealing with these technologies by someone without sufficient knowledge or experience will lead to an increase in the chances of hidden costs. The following comment was provided by an architect on C24 in response to causes of *hidden costs*:

> *"Doing experiments with the technologies and being one of the first adopters will mean higher costs"*

A number of interviewees identified C25 as a trigger for *hidden costs*. They claimed that people who are promoting EERTs and other green products are not providing the public with full details of these products, but only present the advantages of their implementation. This will lead to hidden costs for EERT stakeholders. A project manager commented on C25 when asked about causes of *hidden costs*:

> *"It's common for all the people who sell green products to say that it won't cost you much to go with green products possibly 10% now. Often that 10% raise to 25%, this is for everything green. The Green Building Council and the people that want to influence green technologies tell fibs and they understate how much it will cost to do things"*

C26 was considered to be a trigger for the critical risk *lack of access to funds*. The interviewees believed that many building developers or owners are not interested in investing in EERTs because the investment does not provide instant financial benefits, especially if the building is occupied by a tenant. The tenant will benefit from the savings and the owner will have to deal with any issues related to EERTs. An architect commented on C26 when asked about causes of *lack of access to funds*:

> *"It's a client initiative and depends on the stakeholder interest in the project. I mean why the owner would invest more money when someone else gets the benefits"*

Interviewees identified C27 as the cause of the critical risk *lack of skilled personnel*. They claimed that because the consulting industry in Australia is not risky, fewer people are interested in EERTs and thus less people will be trained to become skilled with these technologies. When asked about causes of *lack of skilled personnel,* a project manager said on C27:

> *"The consulting industry in Australia is very risk-adverse and this is mainly driven by people who don't want to think out of the box!"*

According to the interviewees' opinions, C28 is a trigger for *lack of skilled personnel* and *low consumer demand and acceptance*. As with any new technology or product, people have the tendency to resist change and they feel attached to their old belongings. This might cause people not to be interested in becoming skilled with EERTs or green products. The reaction of people to the demand for and acceptance of EERTs may be similar. The following comment was made by an engineer on C28 when asked about causes of *lack of skilled personnel*:

> *"The cause will just be people doing what they've always done and not adapting to changes in society, environment, or legislative framework"*

C29 was believed to trigger two critical risks: *uncertain availability of incentives* and *uncertain government policies*. Interviewees believed that the government is providing short term solutions and responses to EERTs and green building-related issues. This is occurring because of the lack of knowledge of people working in the government with respect to EERTs and green buildings thus affecting incentives and policies related to EERTs. An engineer made the following comment on C29 when asked about causes of *uncertain availability of incentives*:

"A combination of the global economic crisis and short-sightlessness of government are causing uncertain availability of incentivises. For instance, recently we were responding to a particular economic problem and using that problem to do something good as well as create economic activity and because the government are doing that quickly they didn't put much time in the policy as much as they needed to"

According to interviewees, C30 causes two critical risks: *lack of access to funds* and *uncertain availability of incentives*. They claimed that limited incentives related to EERTs are offered which does not provide sufficient help to stimulate the green building industry. An engineer stated on C30 when asked about causes of *uncertain availability of incentives*:

"The government is not giving the right economic incentives or hasn't got the right policies and not supporting new technologies. The uncertainty is the main issue and from that comes inadequate subsidies that you see"

Interviewees identified C31 as the trigger of four critical risks: *lack of skilled personnel*, *uncertain availability of incentives, uncertain government policies*, and *uncertain payback period*. Unclear goals and regular changes of policies related to EERTs are a major hurdle for industry development bringing uncertainties and affecting individuals and companies making decisions on EERTs. This may be in terms of training personnel or the use of EERTs in projects. The following comment was provided by an engineer on C31 when asked about causes of *uncertain government policies*:

"You can't keep up with the changes of government policies. They keep reinventing them to justify their existence and they don't have clear goals"

C32 was identified by interviewees as a cause of *uncertain availability of incentives*. They said that many EERT stakeholders find difficulties in tracing the incentives available, and some are not even aware of their existence for certain EERTs. The following statement was made by an architect on C32 when asked about causes of *uncertain availability of incentives*:

> *"The particular incentives are not well advertised or not known to stakeholders!"*

Interviewees identified both C33 and C34 as triggers of the critical risk *uncertain government policies*. They argued that because government officials are not knowledgeable about EERTs, wrong policies are announced and many changes to these policies occur. As a result, delays and extra costs occur and affect projects with EERTs. Furthermore, some interviewees claimed that this lack of knowledge is shown in the unserious attitude towards climate change, which also affects EERT policies. The following comments were made by an architect on C33, and a contractor on C34 when asked about causes of *uncertain governmental policies*:

> *"With one of our latest projects, we had to push hard for green technologies to be accepted and had to do with local government and getting them engaged with the processes that they were not familiar with. So, basically the causes are a lack of understanding and exposure to green technologies"*
>
> *"It has to do with not taking the climate change issue seriously and it could be because carbon dioxide is not tangible. I mean it can't be seen in the air as purple bubbles!"*

According to interviewees, C35 causes the critical risk *uncertain payback period*. They believed that the current taxes on EERTs are high and thus keep the cost of EERT implementation high. A project manager commented on C35 when asked about causes of *uncertain payback period*:

> *"Causes are government taxes, such as sale tax on solar panels. As I said before huge taxes are taken from suppliers"*

C36 was thought to trigger the critical risk of *future change in regional climate and weather fluctuation*. Interviewees believed that it is impossible to predict the exact future weather circumstances. The following statement was made by an architect on C36 when asked about causes of *future change in regional climate and weather fluctuation*:

> *"The general unpredictability of weather!"*

Interviewees identified C37 as the trigger of the critical risk of *surface condensation and mould growth*. They said that the behaviour of the end user of EERTs will have an effect on critical risk occurrence. For instance, some EERTs like chilled beams need to be operating under certain humidity conditions but if for some reason the user allows the presence of excess humidity or installs the technology in a humid place, mould growth will occur. The following comment was made by an architect on C37 when asked about causes of *surface condensation and mould growth*:

> *"Poor occupant behaviour such as leaving open doors or windows while the system is in operation"*

5.4.2 Impacts of critical risks

Following the identification of causes of EERT critical risks, interviewees were asked to provide the negative impacts of the 14 critical risks identified from the questionnaire data analysis. In total, they proposed 18 different impacts for EERT critical risks. Table 5-4 lists the impacts of EERT critical risks according to their categories and Table 5-5 lists the impacts of EERTs and their corresponding codes. The impacts of EERT critical risks and opinions of interviewees are discussed in this section.

Table 5-4: Impacts of EERTs critical risks

Code	Impacts of the critical risks of EERTs	Abridged names
I1	Extra financial costs.	Extra costs
I2	Project is subjected to hidden costs.	Hidden costs
I3	Slows the rate at which green industry progresses to maturity.	Deferring green industry maturity
I4	No or slow product development, which can keep prices of technology high.	Sluggish product development
I5	Manufacturers missing out on opportunities due to low user demand.	Missed opportunities
I6	Reputational impact on stakeholders.	Reputational impact on stakeholders
I7	Reputational impact on EERTs.	Reputational impact on EERTs
I8	Technology's under-performance or failure.	Under-performance
I9	Inexperienced design and installation of EERTs due to lack of knowledge accumulated in real applications.	Inexperienced design and installation of EERTs
I10	Delays in project.	Project delays
I11	Best available systems in terms of lifecycle performance not being selected.	Selection mistakes
I12	Difficulty in making decision and planning for the future technology upgrade or building retrofit.	Upgrade planning difficulties
I13	Reluctance of EERT implementation.	Reluctance of implementation
I14	EERTs not being approved by government agencies.	Government approval issues
I15	Confusion as EERT stakeholders do not know where to position themselves in terms of proceeding with green building projects	Stakeholder confusion
I16	Discomfort occupancy space.	Discomfort space
I17	Poor indoor environment quality.	Poor indoor quality
I18	Potential damage to building structure.	Structural damage concern

Table 5-5: EERTs critical risks and their impacts by code

Critical risks	Impacts code
Emergence of new, superior technology	I1, I13
Future change in regional climate and weather fluctuation	I8, I13, I16
Hidden costs	I1, I6, I7, I8, I10, I13
Lack of access to funds	I1, I9, I13
Lack of skilled personnel	I1, I2, I3, I8, I10, I13
Low consumer demand and acceptance	I4, I5
Misplaced incentives	I1, I8, I11, I13
Noise and building vibration	I7, I8, I13, I16, I17, I18
Presence of system constraints	I1, I6, I8, I13
Slow response rate to temperature changes	I13, I16
Surface condensation and mould growth	I8, I13, I17, I18
Uncertain availability of incentives	I3, I12, I13
Uncertain government policies	I1, I6, I10, I13, I14, I15
Uncertain payback period	I1, I13

Interviewees identified I1 as an impact for eight critical risks of EERTs: *emergence of new, superior technology*, *hidden costs*, *lack of access to funds*, *lack of skilled personnel*, *misplaced incentives*, *presence of system constraints*, *uncertain government policies*, and *uncertain payback period*. They said that I1 can be in the form of the owner paying extra to support the operation, maintenance, replacement or upgrade of EERTs. Another form of I1 is when tenants have to pay extra for renting a green office building with EERTs. In addition, there is the high cost of EERT installation in most cases for a high quality job. A contractor commented as follows on I1 when asked about impacts of *lack of access to funds*:

> *"For the client, you will need more funds to deliver the project. For the tenant, they will pay a higher rent to occupy a green office building"*

I2 was identified as an impact for the critical risk of *lack of skilled personnel*. Interviewees claimed that when unskilled personnel are hired for a job involving EERTs, the chances of hidden costs increase. This is because the personnel do not have sufficient knowledge or experience to identify the hidden costs. An architect made the following comment on I2 when asked about impacts of *lack of skilled personnel*:

> *"The project doesn't develop, the hidden costs are not identified, the technical constraints aren't identified, the building is poorly designed, and the building doesn't commission properly"*

Interviewees identified I3 as an impact for two critical risks: *lack of skilled personnel* and *uncertain availability of incentives*. These two critical risks will affect the whole industry development and their occurrence will slow the maturity process. Not having sufficient numbers of skilled personnel means fewer jobs are done correctly and less knowledge is shared among the industry stakeholders. Not having suitable incentives reduces the spread of EERT implementation and thus industry growth. The following statement was provided by an engineer on I3 when asked about impacts of *lack of skilled personnel*:

> *"As a business owner you're not willing to move the business forward. The impact is the slower industry development which needs to go faster"*

I4 and I5 were identified by interviewees as impacts for the occurrence of *low consumer demand and acceptance*. They claimed that if the consumers and end users of EERTs do not demand these technologies at high rates then these technologies will not develop quickly and their prices will stay high. This is because manufacturers will not see the benefit of focusing on that line of production and will start considering alternatives that in some cases may be conventional technologies. As a result, manufacturers will miss opportunities for expansion and the development of new products and markets. The following opinions were expressed by an architect on I4 and a contractor on I5 when asked about impacts of *low consumer demand and acceptance*:

"Not considering these EERTs reduces available options and keeps the prices high because of lower sales quantities"

"Manufactures of EERTs are simply missing out on opportunities"

Interviewees identified I6 as an impact for three critical risks: *hidden costs, presence of system constraints*, and *uncertain government policies*. They argued that reputational damage can happen as a result of these critical risks. The occurrence of hidden risks or system constraints can negatively affect the reputation of the EERT supplier and the personnel installing them as well as the brand name of the companies. As with changed government policies, a change in a policy related to EERTs can affect the timeframe of a project and the relationship between the client and the company. The following view was expressed by an engineer on I6 when asked about impacts of *hidden costs*:

"The impact is inappropriate decision making or decisions that might cost the company financially, environmentally, or reputational impacts. Usually its financial impacts I would say"

According to interviewees, I7 is an impact for the critical risks *hidden costs* and *noise and building vibration*. They stated that the occurrence of these two critical risks will generally affect the reputation of EERTs and as a result will reduce their implementation as owners and end users reject them. The following opinion was given by an engineer on I7 when asked about impacts of *hidden costs*:

"I think it gives EERTs a bad name and also will kill the business case"

I8 was identified as an impact for seven critical risks: *future change in regional climate and weather fluctuation, hidden costs, lack of skilled personnel, misplaced incentives,* *noise and building vibration*, *presence of system constraints*, and *surface condensation and mould growth*. Interviewees said that the occurrence of these seven critical risks will affect the performance of EERTs and in some cases might lead to total failure. For instance, a severe change in weather conditions can affect the energy production of a solar panel thus reducing its performance. In addition, if an EERT is installed by unskilled personnel, damage may occur to the unit which might affect its performance. An engineer commented as follows on I8 when asked about impacts of *misplaced incentives*:

> *"It comes purely to cost via higher maintenance or more frequent refurbishment. Sometimes in the picture of the product not fitting the purpose or not even working at all"*

Interviewees identified I9 as an impact for the critical risk *lack of access to funds*. In many ways scarcity of funds will affect the availability of skilled personnel with experience in and knowledge of EERTs, either by not paying extra funds for the right person or not having the funds to provide training for personnel to become skilled in dealing with EERTs. An architect commented on I9 when asked about impacts of *lack of access to funds*:

> *"The lack of delivery of promised ESD deliverables. Simply the impact is that the building doesn't perform as it should"*

I10 was identified by interviewees as an impact for three critical risks: *hidden costs*, *lack of skilled personnel*, and *uncertain government policies*. They felt that the occurrence of these critical risks will have an impact on project progress and might cause delays. For instance, hidden costs might require the intervention of an external party, which might extend the project time. Changes in government policies can also force changes to project plans and cause delays. A project manager commented on I10 when asked about impacts of *hidden costs*:

> *"You might get a quality problem, a program slippage, longer than expected progress or procurement difficulty for the contractor"*

Interviewees identified I11 as an impact for the critical risk *misplaced incentives*. They argued that some developers and building owners try to achieve green certification for their buildings at the lowest possible cost, in part by selecting the cheapest EERTs available on the market. This could mean that these EERTs are not of high quality and might have uncertain performance in later stages of their lifecycle. An architect stated as follows on I11 when asked about impacts of *misplaced incentives*:

> *"I think the potential impact is not choosing the best overall system when it comes to the lifecycle"*

I12 was considered an impact for the critical risk *uncertain availability of incentives*. Not having sufficient incentives tends to make EERT stakeholders cautious of future involvement with EERTs, including upgrades of building retrofitting. When asked about impacts of *uncertain availability of incentives*, an engineer stated the following on I12:

> *"Difficulty in making decisions and planning for the future which probably prevent manufacturers and various other stakeholders from developing, because they don't want to investment money in an uncertain future"*

Interviewees identified I13 as an impact for all of the critical risks except for *low consumer demand and acceptance*. They believed it is an important impact that will occur if these critical risks happen. People will doubt EERTs if they have critical risks and will be dissatisfied with the technologies or reject them and consider alternatives. A project manager made the following statement on I13 when asked about impacts of *hidden costs*:

> *"I know that we had an early building that was going for 6 stars and was going to be the first in Melbourne. Unfortunately the client pulled off because most of the green technologies that we told him about get to very high prices and when the prices reached a certain level he asked for these technologies to be cancelled. Mainly, it was because the prices were more than he was told and more than we've been told!"*

I14 and I15 were both identified as impacts of the critical risk *uncertain government policies*. Interviewees claimed that sudden changes in government policies or unclear policies related to EERTs will subject these technologies to implementation refusal by councils and government agencies. This will cause confusion among EERT stakeholders. They will be affected by these new polices and this might cost them extra funds or loss of time. The following comments were provided by an architect on I14 and I15 when asked about impacts of *uncertain government policies*:

> *"The risk is that the technologies won't be approved by the government, causing the project not to go ahead and finally having to change the systems which mean extra costs"*
>
> *"I think most of the stakeholders are confused, especially when there is no support from the government, meaning why bother to do it! The occupiers should encourage the government to change the policies"*

According to interviewees, I 16 is an impact for three critical risks: *future change in regional climate and weather fluctuation, noise and building vibration,* and *slow response* *rate to temperature changes*. They claimed that the occurrence of these critical risks can cause many discomforts to the building occupants such as thermal discomfort or noise. A project manager commented the following quote on I16 when asked about the impacts of *future change in regional climate and weather fluctuation*:

> *"The critical risks end up on the asset manager and the users. The impact could be the comfort, functionality, finance of mechanical systems"*

Interviewees identified I17 and I18 as impacts for the two critical risks: *noise and building vibration* and *surface condensation and mould growth*. They believed that these critical risks will lead to an unhealthy environment for the building occupier that might lead to possible health concerns. For instance, mould is known to be medically dangerous for occupants. These critical risks can also cause damage to the building's structure. For example, depending on the intensity of the vibrations caused by wind turbines, these can cause physical damage to the building in the long term. An engineer made the following statement on I17 for the impacts of *surface condensation and mould growth* while a project manager made a comment on I18 for the impact of *noise and building vibration*:

> *"There will be discomfort and potentially it might be unhealthy to use the space that can lead to employees being unproductive which makes it hard to rent the space out"*
>
> *"Will cause problems to the building and annoyance to occupants"*

5.4.3 Measures to manage critical risks

Interviewees provided a wide range of measures to manage the critical risks of EERTs in Australian green office buildings. Some measures were proposed for more than one critical risk such as implementing mature and proven EERTs. Others were proposed for a specific critical risk, such as monitoring and controlling humidity in the case of *surface condensation and mould growth.* A total of 36 managing measures were identified by Interviewees for EERT critical risks. Table 5-6 lists the measures to manage EERTs critical risks and Table 5-7 lists these measures and their corresponding codes. Managing EERTs critical risks and the opinions of industry practitioners are discussed in this section.

Table 5-6: Measures to manage EERTs critical risks

Code	Measures to manage the critical risks of EERTs	Abridged names
M1	Being alert and up-to-date with EERTs market.	Alert with EERTs market
M2	Provide clear advice to the client on the advantages and disadvantages of accessible EERTs.	Clear advice to client
M3	Use of judgmental decisions to align technology options with project objectives and identify the objectives early in the project life.	Use of judgemental decisions
M4	Identifying the costs at an early stage of the project life.	Identifying costs early
M5	Design buildings so they can be adaptable for future EERTs.	Adaptable building design
M6	Implement mature and proven EERTs.	Use mature and proven EERTs
M7	Consider long-term climate cycles in the selection and design of EERTs.	Climate adaptive design of EERTs
M8	Implement energy performance contracting.	Energy performance contracting
M9	Encourage research and development on EERTs.	Encourage research and development
M10	Give more focus on identifying risks comprehensively at early in project life.	Identifying risks early in project
M11	Have experienced and skilled industry practitioners on the team.	Skilled team
M12	Share information and knowledge among industry practitioners.	Information and knowledge sharing
M13	Provide training and education for EERT project teams.	Training and education of project team
M14	Better knowledge and more information sharing amongst the funding institutions with encouragement to lend money to developers or owners if they undertake to deliver green buildings.	Information sharing amongst funding institutions
M15	Appoint independent commissioning agents.	Appoint independent commissioning agents
M16	Involve asset managers during project design stage.	Involve asset managers in design
M17	Tenant demand and involvement during project design stage.	Tenant involvement in design
M18	Provide suitable insulation.	Suitable insulation
M19	Effective control strategy.	Effective control strategy
M20	Improve system design.	Improve system design
M21	Government should make definite policies with clear objectives.	Definite policies with clear objectives
M22	Local authority should inform its clients of any available incentives.	Inform clients of available incentives
M23	Establishing one system that addresses the different tools and models for green building accreditation.	Unified accreditation system
M24	Government needs to be ahead of the industry in awareness and information on EERTs.	Government ahead of industry
M25	Vote for a visionary and strong government.	Vote in appropriate government

Table 5-6 (*continued*): Measures to manage EERTs critical risks

Code	Measures to manage the critical risks of EERTs	Abridged names
M26	Apply green leases.	Green lease
M27	Better feed-in tariff policies.	Feed-in tariff policies
M28	Marketing and consumer education.	Marketing and consumer education
M29	Implement funding schemes.	Special purpose funds
M30	Government provide extra and adequate incentives.	Extra financial support
M31	Set policies that can be open for review in the future in set periods by the public and professionals.	Policies to be open for future review
M32	Provide incentives for EERTs that reduce public infrastructure loads.	Incentives for reduced public infrastructure loads
M33	Establish a contingency plan for EERTs.	Contingency plan
M34	Move from an individual building basis into a whole environmental system basis.	Encourage a whole environmental system
M35	Extended warranties by EERT suppliers and contractors.	Extended warranties
M36	Time and market forces	Time and market forces

Table 5-7: EERTs critical risks and their measures by code

Critical risks	Measures code
Emergence of new and superior technology	M1, M2, M3, M5, M6, M28
Future change in regional climate and weather fluctuation	M6, M7,M8, M9, M19, M34
Hidden costs	M6, M8, M9, M10, M11, M12, M13, M33, M36
Lack of access to funds	M3, M4, M14, M21, M28, M29
Lack of skilled personnel	M12, M13, M36
Low consumer demand and acceptance	M9, M13, M28, M36
Misplaced incentives	M8, M15, M16, M17, M29, M35
Noise and building vibration	M6, M9, M18, M19, M20, M28
Presence of system constraints	M6, M12, M13, M34
Slow response rate to temperature changes	M6, M19, M20, M28
Surface condensation and mould growth	M18, M19, M20, M28
Uncertain availability of incentives	M21, M22, M25, M30
Uncertain government policies	M1, M21, M23, M24, M25, M31, M33
Uncertain payback period	M3, M6, M8, M9, M26, M27, M28, M29, M32

Interviewees emphasised the importance of M1 and considered it a measure for managing the following critical risks: *emergence of new and superior technology* and *uncertain government policies*. They advised all EERT stakeholders to be tuned into industry discussions and alert to any changes to policies or the release of new EERTs. It was also thought to be important to have access to good sources of information to be up-to-date with the industry, and to have a second plan ready for implementation in case any of these changes happened. The following suggestion was made by an architect on M1 when asked about managing *emergence of new and superior technology*.

> *"I suppose its understanding the status of what you're proposing, like where it is in the whole development cycle, and being alert for what is out there and what other things might come out. Also to put in mind whether this is a six month proposition or six years proposition, and what if something else came out? Are you going to replace what you put in or is it going to still be valid"*

According to interviewees, M2 is a measure to manage the critical *risk emergence of new and superior technology*. They believed that it is very important to reveal all positives and negatives of EERTs to clients prior to decision-making. This will give the client a clearer idea about costs and expectations of EERTs, and enhance the reputation of the client's company. The following statement was made by an architect on M2 when asked about managing *emergence of new and superior technology*.

> *"I guess being clear with the clients and letting them know what the disadvantages are. Like unavailability of spare parts in 5 years for this technology and that you will need to replace it by then"*

M3 was thought to be a measure to manage three critical risks: *emergence of new and superior technology*, *lack of access to funds*, and *uncertain payback period*. Interviewees said that it is important to establish project objectives at an early stage and refer to them at each stage of progress. Any decisions making related to EERTs have to be aligned with these objectives throughout the project's life. When asked about solutions for *uncertain payback period*, a project manager said on M3:

> *"Research and understanding what the original objectives of the project are"*

Interviewees identified M4 as a measure to manage the critical risk *lack of access to funds*. They considered that identifying costs of sustainable products early in a project will assist in defining parameters for expenditure and preventing unconsidered future costs. The following suggestion was made by an architect on M4 when asked about managing *lack of access to funds*.

> *"Identify the cost as early as possible and identify the objectives too. So, when someone say sustainable then how much sustainable?"*

Interviewees pointed out the importance of M5 to manage the critical risk *emergence of new and superior technology*. They proposed the design of buildings in a way to allow the implementation of new EERTs. This can be done by having a more general approach in designing these buildings and their areas and not specifically producing designs to accommodate certain EERTs. The following recommendation was given by an engineer on M5 when asked about managing *emergence of new and superior technology*.

> *"The solution to that is when you need refurbishment for your new building you just implement new technologies or you can in design your buildings so it can be able to fit new technologies without issues"*

M6 was recommended as a solution for seven critical risks: *emergence of new and superior technology, future change in regional climate and weather fluctuation, hidden costs, noise and building vibration, presence of system constraints, slow response rate to temperature changes,* and *uncertain payback period*. Some interviewees even commented that it is better to be very conservative when making decisions on EERT selection to avoid reputational damage. This includes not using EERTs with doubtful performance. It is essential to run tests as well as simulations and modelling techniques on EERTs before implementation. A contractor said the following on M6 when asked to propose solutions for *hidden costs*:

> *"Get a better familiarity with these technologies so hidden costs are less likely to occur when it's proven technology. Experience is the key!"*

A number of interviewees recommended M7 as a solution for the critical risk *future change in regional climate and weather fluctuation*. They argued that some people who are promoting climate change issues are not considering sufficient weather cycle profiles for their claims and they should consider weather data for up to 100 years. They also said that the matter should be considered by engineers or any stakeholders who are involved in the EERT selection process for a specific building. A project manager offered the following suggestion on M7 when asked about managing *future change in regional climate and weather fluctuation*

> *"I believe that weather does fluctuate every now and then but some people overdramatised this issue to sell the story. So, records going to 1980s are not enough they have to go back to the 1900s"*

M8 was proposed by interviewees to manage four critical risks *future change in regional climate and weather fluctuation, hidden costs*, *misplaced incentives*, and *uncertain payback period*. Energy performance contracting is a turnkey service, usually guaranteeing that the full project costs will be sufficiently financed by project savings (ICF.International and NAESC, 2007). The contract provides customers with a comprehensive set of energy efficiency, renewable energy and distributed generation measures (ICF.International and NAESC, 2007). Energy performance contracting is usually delivered by energy service companies and consists of four elements: turnkey service, comprehensive measures, project financing, and project savings guarantees (ICF.International and NAESC, 2007). This is an approach that transfers the critical risks of EERTs from the owner to a third party who has sufficient knowledge, experience, and confidence to deal with these technologies throughout their lifecycle. Interviewees also recommended the regulation of energy performance contracting by the government. A project manager commented on M8 when asked to propose solutions for *future change in regional climate and weather fluctuation*:

"Energy performance contracting is also an option where the third party company get part of the energy savings from running a green building to get the payback over the years, but they must put the capital upfront and look further and wider in weather patterns"

Interviewees have suggested M9 as a measure for dealing with five critical risks: *future change in regional climate and weather fluctuation*, *hidden costs, low consumer demand and acceptance*, *noise and building vibration*, and *uncertain payback period*. Transforming markets and reducing barriers to the commercialization and diffusion of emerging technologies is part of a broad innovation-based energy strategy; research and development represent essential components of this strategy (Nemet and Kammen, 2007). In addition to the encouragement of research and development on EERTs, interviewees suggested the availability of more funds by the government for these practices. When asked to propose a solution for *uncertain payback period,* a project manager made the following comment on M9*:*

"Research and understand what the original objectives of the project are"

According to interviewees, M10 and M11 should be done to manage the critical risk *hidden costs*. They recommended the execution of a comprehensive risk identification process in the early stages of any project involving EERTs. This is done to eliminate or at least reduce the number of surprises encountered in the project, given that projects are complex and are often fast-tracked. Furthermore, they emphasised the importance of having skilled personnel on the project team. Skilled personnel are able to identify any risks before they are hidden. The following comments were made by a contractor on M10 and a project manager on M11 when asked about managing *hidden costs:*

"These days a lot of the projects are fast tracked and a lot of things get missed early in the project. This causes you get to a stage where you realise that what you did in a hurry six months ago is actually some hidden costs. That's way things must be done properly in the start so you can know all the costs and you won't encounter in hidden costs latter in the project"

"Appointing a qualified working team that can identify hidden risks and ensure the use of proven technologies"

Interviewees believed that M12 is a measure that can be used to manage the following critical risks *hidden costs*, *lack of skilled personnel*, and *presence of system constraints*. Through knowledge sharing and coordination between industry practitioners, many benefits can be distributed among the industry. This includes the increase in numbers of skilled personnel leading to the elimination or reduction of EERT hidden costs and constraints. An engineer made the following suggestion on M12 when asked to propose measures for *lack of skilled personnel*:

"I think all industry professionals should be sharing information and disclosing lessons learned. Lots of industry professional are doing that anyway because it helps promote their brand or company although I am sure there is lots of intellectual property that's being protected and probably that's slowing the market"

Interviewees suggested that M13 will assist in dealing with critical risks such as: *hidden costs*, *lack of skilled personnel*, *low consumer demand and acceptance*, and *presence of system constraints*. The interviewees agreed that the majority of industry personnel on top of the pyramid are familiar with and well educated in EERTs and their applications. The problem lies with the personnel on the bottom of the pyramid, such as the labourers and tradesmen, who are dealing with installation and maintenance work. Training will lead to an increase in the number of skilled personnel and will eventually result in a reduction in costs. For this purpose, government and large companies should work together on increasing training programs related to EERTs. An engineer offered the following suggestion on M13 when asked to provide a solution to *lack of skilled personnel*:

> *"Better education and training plus introducing a link between what's taught in universities and what happens in practice. Also, more integration between the different engineering disciplines"*

M14 was suggested as a measure for managing the critical risk *lack of access to funds*. Interviewees suggested that funding institutions should have special programs to educate and provide information to their employees on EERTs. Furthermore, funding institutions should provide special types of loans for those who would like to invest in and implement EERTs and green buildings. A contractor made the following suggestion on M14 when asked about solutions for *lack of access to funds*:

> *"One of the solutions that I've seen already is that some of the finance institution when they give money to developers they ask them to make an obligation to deliver a green building. It may not sound very helpful to them but I think at least to say we're going to give you the money if you make sure it's a five star or a six star certified green building. So, I think that a good solution to make it happens"*

Interviewees recommended M15, M16, and M17 as measures for managing the critical risk *misplaced incentives*. They claimed that the appointment of an independent commissioning agent will guarantee the correct assignment of incentives and the protection of those who deserve these incentives. Furthermore, in order to avoid misplaced incentives such as the implementation of low quality EERTs by developers, asset managers should be involved in decision-making with regard to EERTs. The involvement of tenants is also important for managing misplaced incentives. The following comments were made by an engineer on M15, a project manager on M16, and an engineer on M17 when asked to provide measures for managing *misplaced incentives*:

> *"The appointment of an independent commissioning agent, so that the independent party can work on behalf of the people and make sure they get a good product at the end"*
>
> *"Asset managers need to be consulted at the early stages of the briefing to contribute more into the project and lifecycle issues"*
>
> *"Tenant demand is helping, and the new commercial building disclosure legislation is helping a little in terms of energy in existing buildings. So, it's helping in educating tenants more and encouraging them to demand more from the building owners"*

According to interviewees, M18 can be used as a measure for managing the critical risks *noise and building vibration* and *surface condensation and mould growth*. Special types of insulation materials can be used to prevent noise travel in a building. Furthermore, insulation can be used to prevent surface condensation and mould growth. The following suggestion was offered by a contractor on M18 when asked to provide solution for *surface condensation and mould growth*:

> *"Provide insulation to prevent any issues and correct systems if necessary"*

Interviewees suggested M19 as a measure for managing the following critical risks *future change in regional climate and weather fluctuation*, *noise and building vibration*, *slow response rate to temperature changes*, and *surface condensation and mould growth*. They argued that some EERTs require the placement of an effective control strategy. For instance, humidity control and monitoring is required for technologies that might cause mould. Furthermore, some technologies might require the installation of back-up systems to support operation when extreme weather conditions occur or when the occupants' demands cannot be met by the EERTs used. Systematic maintenance was also included as an effective control strategy for EERTs. An engineer made the following comment on M19 when asked to propose solutions for *future change in regional climate and weather fluctuation*:

> *"I think the main one that I would look at is building the system so even if it's right now compatible with the climate it will still get a pack up system. For instance if you have a naturally ventilated space, your back up is to have some space to install air-conditioning in the future"*

M20 was considered as a solution for managing three critical risks: *noise and building vibration*, *slow response rate to temperature changes,* and *surface condensation and mould growth*. Interviewees claimed that some EERTs need to be improved in terms of design to work effectively with fewer risks. The following suggestion was made by an engineer on M20 when asked about managing *noise and building vibration*:

> *"Proper design of systems with better knowledge on them"*

Interviewees identified M21 as a measure for managing three critical risks: *lack of access to funds*, *uncertain availability of incentives,* and *uncertain government policies*. They considered that clear objectives and definite policies should always be provided by governments on EERTs. They also suggested having long-term policies with time frames of up to 20 years to give confidence to EERT stakeholders. Furthermore, they would like to see more policies to encourage people to invest in EERTs and changes those policies which do not. Policies and solutions should be established from the top level of the government. An engineer made the following comment on M21 when asked about solutions for *uncertain governmental policies*:

> *"The government should make more definite policies and be clear of its objectives and what it actually wants"*

Several interviewees identified M22 as a solution for the critical risk *uncertain availability of incentives*. They said that local authorities could help EERT stakeholders to know the incentives offered by the government by notifying them during the permit approval process. The following suggestion was offered by a project manager on M22 when asked about solutions for *uncertain availability of incentives*:

> *"Given that all projects require local authority permission, then perhaps the local authority can be used to inform the clients, developers, consultants of the availability of any incentives that can be applied to projects. This is because you're always going to approach the local government authority during the building design phase in order to get the planning permission"*

According to interviewees, M23 and M24 are solutions for the critical risk *uncertain government policies*. They saw that currently there are too many different tools used for the evaluation of green buildings and they should be united into one system that serves the same purpose. They also saw the need for government entities to be ahead of the industry in awareness, knowledge and information on EERTs. This will assist the development of better policies and pave the way for a mature industry. The following comments were made by a contractor on M23 and an architect on M24 when asked about *uncertain government policies*:

> *"The solution is to have one system that actually replaces all the different tools that are being used at the moment. This makes the terminology much simpler and everyone will know what they're talking about and it will be common practice"*
>
> *"There is a need for a greater awareness of governmental bodies. So the government needs to be ahead of the game"*

M25 was identified by the industry practitioners interviewed as a measure for managing the following risks: *uncertain availability of incentives* and *uncertain government policies*. They believed that the public and EERT stakeholders should take action during elections and vote for the government that they see will implement the right policies and incentives for EERTs. The following statement was made by an architect on M25 when asked about *uncertain availability of incentives*:

> *"Force the government to change the policies! When it comes to voting, select the right government"*

Interviewees identified M26 and M27 as solutions for the critical risk *uncertain payback period*. They thought that the implementation of green leases will help with managing the issues with payback periods of EERTs. This is because a green lease is basically a contract between the owner and tenant to achieve sustainable outcomes. The interviewees also believed that feed-in tariffs policies in Australia are not as good as in other developed countries such as Germany. The feed-in tariffs should be improved, which will lead to better payback periods. The following comments were made by a project manager on M26 and a contractor when asked to provide solutions for *uncertain payback period*:

> *"Having a green lease so that the tenant can see the benefits of these buildings and be ready to pay more"*
>
> *"Feed-in tariffs. Also, incorporate marketing benefits into the payback periods"*

Interviewees have called for M28 as a measure to manage the following critical risks: *emergence of new and superior technology*, *lack of access to funds*, *low consumer demand and acceptance*, *noise and building vibration*, *slow response rate to temperature changes*, *surface condensation and mould growth*, and *uncertain payback period*. They suggested that consumer education should include promotional materials discussing the benefits of EERTs as well as the drawbacks of EERTs and how to manage them, and raise awareness of both the financial and non-financial benefits of EERTs, including the benefits when utility prices increase. Furthermore, it is important to educate consumers on comfort tolerance when using these technologies. At the end, anyone could be the end user of these technologies. A project manager made the following comment on M28 when asked about solutions for *slow response rate to temperature changes*:

> *"Talk the public and end-users into less comfort to save the world"*

Interviewees proposed M29 as a way to manage the three critical risks: *lack of access to funds*, *misplaced incentives,* and *uncertain payback period.* Providing extra funds to EERT stakeholders will definitely help the financial aspects of these critical risks and may also reduce or even eliminate the critical risks in some cases where the gap is caused by insufficient funding. The Property Assessed Clean Energy (PACE) financial arrangement is a type of finance that is provided by the government to property owners who would like to invest in energy efficient and renewable technologies for their homes and commercial buildings (PACE.Now, 2011). These clean energy funds are raised by the government through a variety of sources, such as bonds (Fuller et al., 2009). Property owners who participate in the program repay the finance over a set period of years; this is done through a special tax or assessment added to the property tax bill (Fuller et al., 2009). Another example of government funding schemes is the 1200 building program offered by the City of Melbourne Council. A contractor offered the following when asked to propose a solution for *misplaced incentives*:

> *"The PACE financial arrangement system, which somehow ties the tenants to the owner. It's a successful scheme in the USA, and CH2 is considering this system now"*

M30 was proposed by interviewees as a solution for the critical risk *uncertain availability of incentives*. They argued that current incentives offered by the government for EERTs are not sufficient and more should be given to all EERT stakeholders. A contractor made the following statement on M30 when asked to provide solutions for *uncertain availability of incentives*:

> *"The solution is to have more incentives that apply to all clients, contractors, and tenants as well"*

M31 was identified as a measure for managing the critical risk *uncertain government policies*. Interviewees suggested that policies related to EERTs should be reviewed by the stakeholders in set timeframes if these policies are long-term or need amendments due to changes in circumstances. A project manager made the following comment on M31 when asked about solutions for *uncertain governmental policies*:

"I think that they should put policies that can be open for review later in set periods by the public and professionals"

Interviewees identified M32 as a solution for the critical risk *uncertain payback period*. They thought that extra credit in the form of incentives should go to those EERT owners who reduce the load on public infrastructure. It is a win-win situation for the government and the owners. This will help reduce the costs and extend the life of government infrastructure as well as assist EERT owners with quicker payback for their technologies. A contractor made the following point on M32 when asked about solutions for *uncertain payback period*:

"It's about incentives, so for example if you installed a technology that reduces the load on the public infrastructure then you should be able to get some incentives for that. So, to reduce the payback then you have to find extra ways to give incentives to EERTs owners"

M33 was proposed as a solution for two critical risks *hidden costs* and *uncertain government policies*. Interviewees supported having a contingency plan specifically for EERTs, in case unexpected issues arise from the technology or government policies. An architect suggested the following on M33 when asked to provide solutions for *uncertain government policies*:

"A bit of contingency and being as tuned into the industry discussion as possible so you are alert to prospect to change and be able to cope with it"

Several interviewees identified M34 as a solution for two critical risks *future change in regional climate and weather fluctuation* and *presence of system constraints*. They believed that a holistic environmental system would bring more efficiency to stakeholders compared to individual use of EERTs. This would remove many risks from individual stakeholders and transfer them to those who can handle them better. The following suggestion was made by a contractor on M34 when asked about solutions for *presence of system constraints*:

> *"I think that there is a need to move from looking into individual buildings basis and actually looking into a whole environmental system basis. So, if you have a building then it's probably better to buy green credits than putting your own wind turbine, because you're contributing into something more efficient. Also, consolidating thins into communities, like community chilled water generation or community heat water generation"*

M35 was identified as a solution for the critical risk *misplaced incentives*. To shield EERT owners and users from any manipulations of their technologies, interviewees suggested imposing warranties on EERTs, including obligations by the technology supplier and contractor who carried out the job of installation to correct faults. The following solition was proposed by an engineer on M35 when asked about *misplaced incentives*:

> *"Warranties or extended warranty are a good solution, where the builder has to look after issues and defects occurring during the warranty period"*

Interviewees indicated that M36 would manage the following critical risks: *hidden costs, lack of skilled personnel*, and *low consumer demand and acceptance.* They agreed that, with time, more green projects will be carried out more frequently and market forces in the form of supply and demand will decide whether EERTs will be accepted. An architect made the following comment on M36 when asked to propose solutions for *lack of skilled personnel*:

> *"Time, as more people gets familiar with this stuff and more of it around. Education too making sure that both tradesmen and engineers are exposed to the newest possible technologies, so by the time they are out there working hopefully some of those things will become mainstream"*

5.4.4 Managing stakeholders

The interviewees were asked to identify the stakeholders that they believed could tackle EERT critical risks as part of the critical risk management process. They had the freedom to choose from any stakeholders without being limited to a certain list of stakeholders. Some interviewees identified one managing stakeholder for each critical risk, while others identified more than one stakeholder for each critical risk. A total of 10 different stakeholders were identified as the best to manage EERT critical risks. Several interviewees identified all of the stakeholders as managing stakeholders in some cases. Table 5-8 lists the different managing stakeholders, codes, and interest in green office building EERTs identified, and Table 5-9 presents the interviewees' opinions on the managing stakeholders of EERTs.

Table 5-8: list of best managing stakeholders, codes, and interest in green office building EERTs

Managing stakeholder	Code	Interest in green office building EERTs
Architect	S1	Overall aesthetic view of the building and EERTs
Contractor	S2	Achievement of construction activities
Engineer	S3	Success of design and operation of the building and EERTs
Facility manager	S4	Supervision, maintenance, security, and cleanness of the building and EERTs
Government	S5	Achievement of sustainable measures and legislation
Industry experts	S6	Success of project, knowledge sharing, and industry maturity
Occupier	S7	A building that is environmentally friendly with healthy space
Owner/developer	S8	Successful implementation of the building and EERTs throughout the lifecycle
Project manager	S9	Delivery, planning, and execution of the building and EERTs
Supplier	S10	Profits through sales of quality materials and technologies
All stakeholders	S0	Accomplishment and success of project

Table 5-9: Critical risks and managing stakeholders number of times mentioned by interviewees

Critical risks	**Managing stakeholders**										
	S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Emergence of new and superior technology	1	3		8						2	3
Future change in regional climate and weather fluctuation	1	1		5		2	1				
Hidden costs				5					3	7	1
Lack of access to funds	1			1		1			4	4	
Lack of skilled personnel	2		1	2		1	4		1	2	2
Low consumer demand and acceptance			1	5		1					4
Misplaced incentives	1					4		3	2	5	
Noise and building vibration		2	1	5						1	3
Presence of system constraints	2			7	1	3			2	2	3
Slow response rate to temperature changes			1	7				1	2		1
Surface condensation and mould growth		1		6	2				1		
Uncertain availability of incentives		1		1		3		1	1	4	1
Uncertain government policies	5		1	2		6		2	2	2	
Uncertain payback period	4			4	3	2		2		2	
Total	17	8	5	58	6	23	5	9	18	31	18

From Table 5-9, it is clear that the interviewees see engineers as the best stakeholders to manage all EERT critical risks, with the exception of *misplaced incentives*, being mentioned 58 times. Following engineers as best managers of EERT critical risks are project managers, who were mentioned 31 times to manage 10 critical risks. Stakeholders who were mentioned often were the government, owners/developers, suppliers and all stakeholders at 23, 18, 18, and 17 times respectively, to manage 9, 9, 8, and 8 critical risks respectively. Interviewees mentioned four stakeholders in the relatively low range: occupiers, facility managers, contractors, and industry experts were mentioned 9, 6, 5, and 5 times to manage 5, 3, 5, and 2 critical risks respectively.

A particular assumption was made for the selection of the managing stakeholders for each critical risk. Any stakeholder mentioned only once for one particular critical risk was not included in the prioritization process. Based on this assumption Table 5-10 was created listing the critical risks and their managing stakeholders with prioritisation for those stakeholders who were mentioned most by interviewees.

Table 5-10: Critical risks and their prioritized best managing stakeholders

Critical risks	Prioritisation of managing stakeholders			
	1st	2nd	3rd	4th
Emergence of new and superior technology	S3	S1, S10	S9	
Future change in regional climate and weather fluctuation	S3	S5		
Hidden costs	S9	S3	S8	
Lack of access to funds	S8, S9			
Lack of skilled personnel	S6	S0, S3, S9, S10		
Low consumer demand and acceptance	S3	S10		
Misplaced incentives	S9	S5	S7	S8
Noise and building vibration	S3	S10	S1	
Presence of system constraints	S3	S5, S10	S0, S8, S9	
Slow response rate to temperature changes	S3	S8		
Surface condensation and mould growth	S3	S4		
Uncertain availability of incentives	S9	S5		
Uncertain government policies	S5	S0	S3, S7, S8, S9	
Uncertain payback period	S0, S3	S4	S5, S7, S9	

In terms of priority, Table 5-10 illustrates that interviewees gave engineers the first priority to manage eight critical risks: *emergence of new and superior technology*, *future change in regional climate and weather fluctuation*, *low consumer demand and acceptance*, *noise and building vibration*, *presence of system constraints*, *slow response rate to temperature changes*, *surface condensation and mould growth*, and *uncertain payback period*. They gave project managers the first priority to manage four critical risks: *hidden costs*, *lack of access to funds*, *misplaced incentives*, *uncertain availability of incentives*. Interviewees gave the first priority to owners/developers to manage *lack of access to funds*, to industry experts to manage *lack of skilled personnel*, to the government to manage *uncertain government policies*, and to all stakeholders to manage *uncertain payback period*.

As a result, engineers, project managers, and owners/developers represent the most important stakeholders for managing EERTs critical risks. These stakeholders should always be involved in managing the critical risks of EERTs from the start and throughout the lifecycle of EERTs and green office buildings.

5.4.5 Lifecycle stages of action

Similarly to the identification of the managing stakeholders, in this step interviewees were asked to identify the lifecycle stages of action for managing the critical risks done as part of the EERT critical risk management process. Interviewees had freedom of choice of any lifecycle stage they saw as appropriate without being limited to a fixed list of lifecycle stages. Some identified one lifecycle stage for action against each critical risk, while others identified more than one lifecycle stage for action against each critical risk. A total of four different lifecycle stages of action were identified as the best timing to take measures against critical risks. Several interviewees identified all of the lifecycle stages as the best times of action in some cases. Table 5-11 lists the different lifecycle stages identified and Table 5-12 presents their opinions on the lifecycle stages of action for critical risks.

Table 5-11: List of lifecycle stages of action and their codes

Lifecycle stage	Code
Concept stage	L1
Design stage	L2
An industry issue that should be addressed as soon as possible	L3
Operation and maintenance stage	L4
Throughout the lifecycle	L0

Table 5-12: Critical risks and lifecycle stages: Number of times mentioned by interviewees

Critical risks	Lifecycle stages of action				
	L0	L1	L2	L3	L4
Emergence of new and superior technology		5	8		
Future change in regional climate and weather fluctuation	1	6	3		
Hidden costs		7	5		3
Lack of access to funds		5	2	3	
Lack of skilled personnel		5		9	
Low consumer demand and acceptance			6	3	
Misplaced incentives		7	4	2	
Noise and building vibration			8		
Presence of system constraints	1	6	7		
Slow response rate to temperature changes			6		1
Surface condensation and mould growth	2		5		2
Uncertain availability of incentives		4	2	5	
Uncertain government policies		4	4	9	
Uncertain payback period	4	5	3		3
Total	8	54	63	31	9

Table 5-12 shows that interviewees mentioned the design stage as the best lifecycle stages for taking action against all of the critical risks, with the exception of *lack of skilled personnel*, with 63 mentions. The concept stage came second, being mentioned 54 times for action against 10 critical risks. Many interviewees identified taking action against critical risks as soon as possible as best for six critical risks, with 31 mentions. The two lifecycle stages mentioned least often were throughout the lifecycle and operation and maintenance, with 8 and 9 mentions respectively, both for taking action against four critical risks.

A similar assumption to that made for the selection of managing stakeholders was made with the selection of the lifecycle stages of action for each critical risk. Any lifecycle stage that was mentioned only once for one particular critical risk was not included in the prioritization process. Based on this assumption, Table 5-13 was created listing the critical risks and their lifecycle stages of action with prioritisation for those lifecycle stages mentioned most often.

Table 5-13: Critical risks and their prioritized lifecycle stages of action

Critical risk	Prioritisation of lifecycle stages of action		
	1st	2nd	3rd
Emergence of new and superior technology	L2	L1	
Future change in regional climate and weather fluctuation	L1	L2	
Hidden costs	L1	L2	L4
Lack of access to funds	L1	L3	L2
Lack of skilled personnel	L3	L1	
Low consumer demand and acceptance	L2	L3	
Misplaced incentives	L1	L2	L3
Noise and building vibration	L2		
Presence of system constraints	L2	L1	
Slow response rate to temperature changes	L2		
Surface condensation and mould growth	L2	L0, L4	
Uncertain availability of incentives	L3	L1	L2
Uncertain government policies	L3	L1, L2	
Uncertain payback period	L1	L0	L2, L4

From Table 5-13, it can be seen that interviewees identified the design stage as the top priority for action against six critical risks: *emergence of new and superior technology*, *low consumer demand and acceptance*, *noise and building vibration*, *presence of system constraints*, *slow response rate to temperature changes*, and *surface condensation and mould growth*. The concept stage was identified as the first priority for action against five critical risks: *future change in regional climate and weather fluctuation*, *hidden costs*, *lack of access to funds*, *misplaced incentives*, and *uncertain payback period*. Interviewees identified the first priority as the industry and the need to be addressed as soon as possible to three critical risks: *lack of skilled personnel*, *uncertain availability of incentives*, and *uncertain government policies*.

This section has shown that, in general the design stage is the first priority for action against critical risks with technical and informational aspects. The concept stage is the first priority for action against critical risks with financial aspects, and the industry is the first priority for action against critical risks with political and skills training aspects.

5.5 Findings of interview data analysis

In interviews, 20 industry practitioners provided their feedback on the causes of EERTs critical risks, their impacts, measures to be taken, managing stakeholders, and lifecycle stages of action. The main findings are as follows:

- 37 different causes have been identified for the occurrence of EERTs critical risks.
- 18 different impacts have been identified for the occurrence of EERTs critical risks.
- 36 measures have been identified for the management of EERTs critical risks.
- A total of 10 different stakeholders have been identified as best for managing EERTs critical risks.
- Engineers, project managers, and owners/developers are the most important of the stakeholders for managing EERTs critical risks.
- Four different lifecycle stages of action have been identified as the best times to take measures against EERTs critical risks.
- The design stage is the first priority for action against critical risks with technical and informational aspects, the concept stage is the first priority for action against critical risks with financial aspects, and the industry stage is the first priority for action against critical risks with political and skills training aspects.

CHAPTER 6: FRAMEWORK DEVELOPMENT AND VALIDATION

6.1 Introduction

The previous chapters worked on collecting data and analysing them to come up with findings that are important to the stakeholders of green office building using EERTs. It starts with a comprehensive literature review on the research topic with a major finding of identifying the EERTs to be used in this research and the 30 potential risks of these EERTs implemented in green office buildings. Chapter 4 displays the findings of the survey questionnaire which included the critical risks of EERTs, the affected stakeholders, and the likely lifecycle stage of impact for these risks. Chapter 5 illustrated the findings of a series of semi-structured interviews that enables the stakeholders of the green office building EERTs to know how to tackle its potential critical risks and know the managing stakeholder for these critical risks and the lifecycle stage to take action against them. All these outcomes need to be integrated into one vehicle that makes it more convenient and helpful for the stakeholders to refer.

This chapter incorporates all of the results previously reported in a framework developed to help the stakeholders of Australian green office building EERTs deal with the risks of these technologies and to enable them to predict the risks (see Figure 6.1). The framework integrates the risk management process, the stakeholder analysis, and the lifecycle asset management model, with the risk management process being the backbone of the framework. The potential use of the framework is also discussed, and at the end of this chapter, two case studies validating the framework are presented.

6.2 Purpose of Framework

The framework aims to incorporate the findings of the literature review, questionnaires, and semi-structured interviews into one vehicle which is easy for stakeholders of Australian green office building EERTs to use. Specifically, it identifies eight significant elements for stakeholders with regard to their green office building EERTs: 1. Potential critical risks, 2. Affected stakeholders, 3. Likely lifecycle stages of risk occurrence, 4. Causes of critical risks, 5. Impacts of critical risks, 6. Managing stakeholders, 7. Lifecycle stages of action, and 8. Measures to manage the critical risks.

6.3 Framework Formulation

The present research framework is formulated by the integration of three theories: risk management process, stakeholder analysis, and lifecycle asset management model. The main six steps of the framework were adopted from the risk management process, these are: 1. Communication and consultation, 2. Establish the context, 3. Identification, 4. Risk analysis and evaluation, 5. Treatment, and 6. Monitor and review. Stakeholder analysis was adopted in the research framework. This is mainly in the form of identifying the key stakeholders who are affected or can have an influence on the green office buildings EERTs. Green office buildings are considered as assets, the present research framework takes into consideration the lifecycle stages to address EERTs critical risks. The different lifecycle stages were adopted in this research framework to assist in identifying the lifecycle stage at which occurs as well as the best time to take action against these risks during the asset lifecycle.

6.4 Framework Development

This section presents details of the framework and the six major steps in it. The steps are: 1. Communication and consultation, 2. Establish the context, 3. Identification, 4. Risk analysis and evaluation, 5. Treatment, and 6. Monitor and review. It also provides details of the framework.

6.4.1 Communication and consultation

Communication and consultation can help identify critical risks and find solutions. For instance, organizations can learn how to identify and manage a certain risk from another organization that has managed that risk effectively (AS/NZS, 2004). Another example can be the different perceptions of the organization members. As each member has his/her own perception and point of view on the risk solution, when all are integrated together they will provide a better solution (AS/NZS, 2004).

At the start of each step of the risk management process for the EERTs implemented in green office buildings communication and consultation with the internal and external stakeholders should take place. This will assist the better execution of the risk management process, and in addition the stakeholders will help provide up-to-date information on the selected EERTs. The engagement of internal and external stakeholders in the field of EERTs and green buildings is important as they have the latest insights and sufficient experience to provide advice.

6.4.2 Establish the context

In this step, the goals, objectives, strategies, scope, and parameters of the risk management process of the organization should be set, and the relationships between the organization and the external environment related to the EERTs should be defined (AS/NZS, 2004). For instance, this may include businesses, competitor organizations, and regulatory and financial institutions, as well as the external stakeholders of the organization and its key business drivers (AS/NZS, 2004). Moreover, the strengths, weaknesses, opportunities and threats of the organization should be taken into account before the commencement of any activity related to risk management, the internal context of the organization should be defined, including the organizational culture, internal stakeholders, structure, capabilities, goals, objectives, and strategies (AS/NZS, 2004).

With respect to the present research, it is very important to establish the goals, objectives, scope, and parameters of the risk management process conducted for green office building EERTs and identify the EERTs to be investigated in the process. Based on knowledge of which EERTs are included in the investigation, future steps in the process will be facilitated. Furthermore, the scope of the risk management process to be applied to the green office building EERTs should be defined, including all aspects to be included or excluded from the process.

The main goals of using EERTs were identified previously in Chapter 2, and must be considered when establishing the context. The goals are:

1. Create less environmental damage than existing technologies,
2. Treat and prevent environmental damage,
3. Create less pollution with fewer emissions and less waste,
4. Manage resources more efficiently with reduced energy and resource consumption,
5. Provide economic advantages.

These goals should be considered when setting up the goals, objectives, scope, and parameters of the risk management process, to ensure that these goals are achieved. Any obstacles to these goals should be included in the scope of the risk management process.

6.4.3 Identification

In order to identify the risks, it is important to have good quality information (AS/NZS, 2004). This can be achieved by examining historical data, expert opinions, interviews, focus group discussions, strategic and business plans, insurance claim reports, surveys and questionnaires (AS/NZS, 2004).

The 14 critical risks of green office building EERTs have already been identified in the framework and are listed in Table 6-1. Stakeholders can refer to these critical risks and review them in the context of their green office building EERTs. This will give them an indication of what to expect from the implementation of these technologies. These risks do not necessarily represent all risks of EERTs but are the most critical risks identified by the industry practitioners who participated in the study. Hence, this list provides a good starting point for those who seek the informed advice of professional industry practitioners. Moreover, the stakeholders affected by these critical risks have been identified. This also gives an indication to green office building EERTs stakeholders of which stakeholders may be affected by the critical risk. See Table 6-1. The framework also identifies the lifecycle stages at which these critical risks are likely to occur, based on the perception of industry practitioners who participated in the study, allowing framework users to know when during the lifecycle stage they may expect the critical risks to occur. For the full list of risks with details of the affected stakeholders and the likely lifecycle stages of occurrence, refer to Chapter 4.

Table 6-1: Critical risks, affected stakeholders and likely lifecycle stages of occurrence

Critical risks	Affected stakeholders	Likely lifecycle stages of occurrence
Emergence of new and superior technology	1st owner, 2nd engineer.	Throughout the lifecycle
Future change in regional climate and whether fluctuation	1st owner, 2nd occupier, 3rd engineer.	1st operation.
Hidden costs	1st owner.	1st operation, 2nd constriction.
Lack of access to funds	1st owner.	1st concept, 2nd design.
Lack of skilled personnel	1st contractor, 2nd project manager.	1st construction, 2nd operation.
Low consumer demand and acceptance	1st owner, 2nd supplier.	1st concept, 2nd design.
Misplaced incentives	1st owner.	1st concept.
Noise & building vibration	1st occupier, 2nd owner.	1st operation.
Presence of system constraints	1st engineer.	1st design, 2nd concept.
Slow response rate to temperature changes	1st occupier, 2nd owner.	1st operation.
Surface condensation and mould growth	1st occupier, 2nd owner.	1st operation.
Uncertain availability of incentives	1st owner.	1st concept, 2nd operation.
Uncertain government policies	1st owner.	1st concept.
Uncertain payback period	1st owner.	1st concept, 2nd operation, 3rd design.

6.4.4 Risk analysis and evaluation

The analysis and evaluation step must be done for one EERT at a time. Accountable stakeholders using the framework should refer to the EERTs identified in Step two of the framework and select one EERT for analysis and evaluation at a time.

6.4.4.1 Analysis

Risk source, negative consequences and likelihood of occurrence are considered in this step (AS/NZS, 2004). Statistical analysis and calculations can be used to estimate both the consequence and likelihood of the risk (AS/NZS, 2004). In cases where no reliable data is available, individual and group estimates are used to give a relative indication of the consequences and the likelihood of an event (AS/NZS, 2004). Various degrees of risk analysis can be undertaken depending on the risk, the purpose of the analysis, and the availability of information, data, and resources (AS/NZS, 2004). Three types of analysis can be used: qualitative, semi-quantitative and quantitative (AS/NZS, 2004). Qualitative analysis is used to give a broad idea of the risk level, as it depends on the use of words to describe the consequences and likelihood of an event (AS/NZS, 2004). It can be used where numerical data is not reliable or available (AS/NZS, 2004). Semi-quantitative analysis is used to give a better ranking scale than that used in qualitative analysis by adding numerical values to the qualitative scale (AS/NZS, 2004). The numerical values used in the semi-quantitative scale do not reflect the actual extent of the consequences or likelihood of an event (AS/NZS, 2004). Quantitative analysis is used for a more accurate analysis, where numerical values are used for both the consequence and likelihood of the risk (AS/NZS, 2004). The results of this type of analysis depend on the accuracy of the numerical values used (AS/NZS, 2004).

For the selected EERT, the accountable stakeholder team should investigate whether the identified critical risks from Step 3 (Identification) are applicable to the selected technology. They can then carry out the analysis by using the semi-quantitative method described in this section. All analysis should be based on the project context. Before starting the analysis, the team can study both the causes and impacts of the identified critical risks in order to gain a sense of industry practitioners' perceptions of these critical risks to assist the team with decision-making in the analysis part. See Tables 6-2 and 6-3 for causes and impacts of critical risks.

Table 6-2: Causes of EERTs critical risks

Critical risks	Causes
Emergence of new and superior technology	- The introduction of new more effective EERTs at a fast pace making previous versions redundant. - Lack of information and awareness among EERTs stakeholders. - Market forces and innovation.
Future change in regional climate and weather fluctuation	- The design of EERTs specifically for certain climate profile, leading to difficulties for these technologies to react to weather fluctuation and climate change. - New technologies in general have less capacity and fewer safety factors in design compared to old technologies making them more fragile to weather fluctuation and climate change. - Professionals selecting EERTs not considering sufficient timeframes for weather cycles. - The unpredictability of weather.
Hidden costs	- Being one of EERTs first adopters without having sufficient experience. - Green Building Council, suppliers and people promoting the use of EERTs providing the public with incorrect information. - Suppliers and contractors increasing their costs as soon as they know that potential owners of EERTs are seeking them for reasons apart from financial costs. - Lack of knowledge, education and training among industry practitioners. - Poorly specified projects and unsuitable contract conditions.
Lack of access to funds	- Clients and developers mostly concerned with financial aspects of EERTs and not considering other aspects such as environment, marketing and quality. - Not recognizing EERTs costs at early stages of project. - Government not offering the right economic incentives for EERTs and being cautious in providing funding - Developers or clients not interested to invest in technologies that do not have instant results, especially when the developer or owner does not have to deal with ongoing costs. - High capital cost of EERTs. - Lack of information and awareness among EERT stakeholders.
Lack of skilled personnel	- Lack of knowledge, education and training among industry practitioners. - The selection of unqualified people for a job involving EERTs. - Limited number of projects incorporating EERTs. - Insufficient financial incentives for industry practitioners to become skilled with EERTs. - Consulting industry in Australia being very risk adverse. - Personnel on the top of the pyramid are well educated on EERTs but the issue lies with personnel on the bottom of the pyramid. - Resistance to change. - Companies’ failure to provide sufficient support to invest in staff training. - Constant policy changes and no clear goals.

Table 6-2 (*continued*): Causes of EERTs critical risks

Critical risks	Causes
Low consumer demand and acceptance	- High capital cost. - Unproven technology. - Lack of information and awareness among EERTs stakeholders. - Resistance to change.
Misplaced incentives	- Developers installing EERTs in order to acquire a green building rating without taking into account the soundness or quality of these technologies. - Clients and developers mostly concerned with financial aspects of EERTs and not considering other aspects such as environment, marketing and quality.
Noise and building vibration	- System limitation. - Lack of knowledge, education and training among industry practitioners.
Presence of system constraints	- Lack of knowledge, education and training among industry practitioners. - Unproven technology. - Industry practitioners not having a holistic view, as most practitioners are only knowledgeable in their own field of practice. - Lack of knowledge, education and training among industry practitioners.
Slow response rate to temperature changes	- System limitation.
Surface condensation and mould growth	- System limitation. - The design of EERTs specifically for certain climate profiles, leading to difficulties for these technologies to react to weather fluctuation and climate change. - Poor occupant behaviour.
Uncertain availability of incentives	- Government not dedicating sufficient time to policies related to EERTs and sightlessness. - Government not offering the right economic incentives for EERTs and being cautious in providing funding. - Constant policy change and no clear goals. - Stakeholders not being aware of accessible incentives or how to claim tem.
Uncertain government policies	- Government not dedicating sufficient time to policies related to EERTs and sightlessness. - Government lacking understanding and exposure to EERTs. - Constant policy change and no clear goals. - Existence of different schemes, models, and tools for green building accreditation. - Government not taking climate change seriously.

Table 6-2 (*continued*): Causes of EERTs critical risks

Critical risks	Causes
Uncertain payback period	- Clients and developers mostly concerned with financial aspects of EERTs and not considering other aspects such as environmental, marketing and quality. - Unproven technology. - Taxes imposed by government increasing costs of EERTs. - High capital cost of EERTs. - Constant policy changes and no clear goals. - Uncertainty in the prediction of future electricity and water prices.

Table 6-3: Impacts of EERTs critical risks

Critical risks	Impacts
Emergence of new, superior technology	- Reluctance of EERTs implementation. - Extra financial costs.
Future change in regional climate and weather fluctuation	- Discomfort occupancy space. - Technology under-performance or failure. - Reluctance of EERTs implementation.
Hidden costs	- Extra financial costs. - Technology under-performance or failure - Delays in project. - Reputational impact on stakeholders. - Reputational impact on EERTs. - Reluctance of EERTs implementation.
Lack of access to funds	- Reluctance of EERTs implementation. - Extra financial costs. - Inexperienced design and installation of EERTs due to lack of knowledge accumulated in real applications.
Lack of skilled personnel	- Reluctance of EERTs implementation. - Technology under-performance or failure. - Delays in project. - Project is subjected to hidden costs. - Extra financial costs. - Slows the rate at which green industry progress to become mature.
Low consumer demand and acceptance	- No or slow product development, which can keep prices of technology high. - Manufacturers missing out on opportunities due to low user demand.
Misplaced incentives	- Best available systems in terms of lifecycle performance not being selected. - Reluctance of EERTs implementation. - Extra financial costs. - Technology under-performance or failure.
Noise and building vibration	- Poor indoor environment quality. - Discomfort occupancy space. - Reputational impact on EERTs. - Potential damage to building structure. - Technology under-performance or failure. - Reluctance of EERTs implementation.

Table 6-3 (*continued*): Impacts of EERTs critical risks

Critical risks	Impacts
Presence of system constraints	- Reluctance of EERTs implementation. - Technology under-performance or failure. - Extra financial costs. - Reputational impact on stakeholders.
Slow response rate to temperature changes	- Discomfort occupancy space. - Reluctance of EERTs implementation.
Surface condensation and mould growth	- Poor indoor environment quality. - Potential damage to building structure. - Reluctance of EERTs implementation. - Technology under-performance or failure.
Uncertain availability of incentives	- Difficulty in making decisions and planning for future technology upgrade or building retrofit. - Slows the rate at which green industry progresses to maturity. - Reluctance of EERTs implementation.
Uncertain government policies	- Reputational impact on stakeholders. - Delays in project. - Extra financial costs. - Confusion as EERTs stakeholders do not know where to position themselves in terms of proceeding with green building projects. - Reluctance of EERTs implementation. - EERTs not betting approved by government agencies.
Uncertain payback period	- Reluctance of EERTs implementation. - Extra financial costs.

The analysis starts by assigning a likelihood and consequence value for each critical risk of the selected EERT. As explained previously in Chapter 4, the value of the level of risk gives an indication of the significance of the critical risk with respect to the opinion of the team using the framework and makes it easier for them to later make a decision on evaluation and treatment. Equation 6-1 can be used to obtain a value for the level of risk.

Equation 6-1: Level of risk

$$Level\ of\ risk = Likelihood \times Consequence$$

Values for likelihood and consequence can be taken from Tables 6-4 and 6-5 respectively:

Table 6-4: Likelihood scale

Likelihood	Description	Rank
Almost certain	The critical risk is very highly expected to occur	5
Likely	The critical risk is highly expected to occur	4
Possible	The critical risk might occur	3
Unlikely	The critical risk is unexpected to occur	2
Rare	The critical risk is very unexpected to occur	1

Table 6-5: Consequence scale

Consequence	Description	Rank
Severe	The occurrence of the critical risk will not achieve the purpose of the EERT or building	5
Major	The occurrence of the critical risk will not achieve the major purpose of the EERT or building	4
Moderate	The occurrence of the critical risk will affect some of the purpose of the EERT or building	3
Minor	The occurrence of the critical risk will have a minor affect on the purpose of the EERT or building	2
Negligible	The occurrence of the critical risk will have a controllable affect on the purpose of the EERT or building	1

After calculating the level of risk for each critical risk, Table 6-6 can be used to gain an idea of the significance of the critical risks, based on the new analysis by the team using the framework and taking into consideration the project context.

Table 6-6: Risk matrix

Likelihood	Consequence				
	Negligible (1)	Minor (2)	Moderate (3)	Major (4)	Severe (5)
Almost certain (5)	Medium	Medium	Critical	Critical	Critical
Likely (4)	Low	Medium	Critical	Critical	Critical
Possible (3)	Low	Medium	Medium	Critical	Critical
Unlikely (2)	Low	Low	Medium	Medium	Medium
Rare (1)	Low	Low	Low	Low	Medium

6.4.4.2 Evaluation

Organizational objectives and other risk criteria that were set in the establishment of context step are considered in the evaluation of risks (AS/NZS, 2004). Critical risk evaluation is based on the results of the analysis, where treatment prioritization is carried out among all critical risks with reference to Table 6-6, followed by a decision on whether specific critical risks need treatment. Treatment should be carried out at least for medium and critical risks, because all risks on the table were classified originally as critical by the industry practitioners who participated in the study. However, this assessment may vary with different green office building EERTs. The major goals of EERTs should also be considered in the evaluation process, as risks influencing these goals must be considered with great care.

All information gathered from the analysis and evaluation can be inserted in Table 6-7, which is to be completed by the accountable stakeholder team.

Table 6-7: Risk register

EERT selected for analysis and evaluation:						
Critical risks	**Critical risk applicable to selected EERT Y/N**	**Analysis**			**Evaluation**	
		Likelihood	**Consequence**	**Level of risk**	**Treatment prioritization**	**Needs treatment Y/N**
Emergence of new and superior technology						
Future change in regional climate and whether fluctuation						
Hidden costs						
Lack of access to funds						
Lack of skilled personnel						
Low consumer demand and acceptance						
Misplaced incentives						
Noise & building vibration						
Presence of system constraints						
Slow response rate to temperature changes						
Surface condensation and mould growth						
Uncertain availability of incentives						
Uncertain government policies						
Uncertain payback period						

6.4.5 Treatment

When selecting the treatment option, it is very important to consider the costs of implementing this option and the benefits resulting from it (AS/NZS, 2004). All factors, such as direct and indirect costs or tangible and intangible benefits should be considered in this step (AS/NZS, 2004). Treating a risk can be done by selecting one treatment option or a combination of treatment options (AS/NZS, 2004). In some cases, new risks might be identified during or after the risk treatment step (AS/NZS, 2004).

Once again, for the selected EERT and after carrying out the analysis and evaluation steps, the accountable team can start the treatment step. The framework provides its users with the necessary information to manage the critical risks. The team can start by selecting the managing stakeholders from Table 6-8. The stakeholders selected are the best persons to manage the critical risk according to the opinions of the industry practitioners who participated in the present study. Subsequently, the team can select the lifecycle stages of action from Table 6-9, which gives them what the interviewees believed is the best time to manage the critical risk. Finally, the team can select from Table 6-10 the measures proposed by the participating industry practitioners to manage the critical risks of the selected EERT.

Table 6-8: Managing stakeholders

Critical risks	Prioritisation of managing stakeholders			
	1st	2nd	3rd	4th
Emergence of new and superior technology	S3	S1, S10	S9	
Future change in regional climate and weather fluctuation	S3	S5		
Hidden costs	S9	S3	S8	
Lack of access to funds	S8, S9			
Lack of skilled personnel	S6	S0, S3, S9, S10		
Low consumer demand and acceptance	S3	S10		
Misplaced incentives	S9	S5	S7	S8
Noise and building vibration	S3	S10	S1	
Presence of system constraints	S3	S5, S10	S0, S8, S9	
Slow response rate to temperature changes	S3	S8		
Surface condensation and mould growth	S3	S4		
Uncertain availability of incentives	S9	S5		
Uncertain government policies	S5	S0	S3, S7, S8, S9	
Uncertain payback period	S0, S3	S4	S5, S7, S9	

Table 6-9: Lifecycle stages of action

Critical risk	Prioritisation of lifecycle stages of action		
	1st	2nd	3rd
Emergence of new and superior technology	L2	L1	
Future change in regional climate and weather fluctuation	L1	L2	
Hidden costs	L1	L2	L4
Lack of access to funds	L1	L3	L2
Lack of skilled personnel	L3	L1	
Low consumer demand and acceptance	L2	L3	
Misplaced incentives	L1	L2	L3
Noise and building vibration	L2		
Presence of system constraints	L2	L1	
Slow response rate to temperature changes	L2		
Surface condensation and mould growth	L2	L0, L4	
Uncertain availability of incentives	L3	L1	L2
Uncertain government policies	L3	L1, L2	
Uncertain payback period	L1	L0	L2, L4

Table 6-10: Measures to manage the critical risks of EERTs

Critical risks	Measures to manage the critical risks of EERTs
Emergence of new and superior technology	- Be alert and up-to-date with EERTs market. - Provide clear advice to the client on the advantages and disadvantages of accessible EERTs. - Use of judgmental decisions to align technology options with project objectives. - Design buildings so they can be adaptable for future EERTs. - Implement mature and proven EERTs. - Marketing and consumer education..
Future change in regional climate and weather fluctuation	- Consider long-term weather cycle in the selection and design of EERTs. - Implement energy performance contracting. - Implement mature and proven EERTs. - Effective control strategy. - Encourage research and development on EERTs. - Move from an individual building basis into a whole environmental system basis
Hidden costs	- Encourage research and development on EERTs. - Establish a contingency plan for EERTs. - Give more focus to identifying risks comprehensively at early project life. - Have experienced and skilled industry practitioners on the team. - Implement energy performance contracting. - Implement mature and proven EERTs. - Share information and knowledge among industry practitioners. - Provide training and education for EERTs project teams. - Time and market forces.
Lack of access to funds	- Share information and knowledge amongst the funding institutions with encouragement to lend money to developers or owners if they make an obligation to deliver green buildings. - Government should make definite policies with clear objectives. - Identify the costs and early stage of the project life. - Use of judgmental decisions to align technology options with project objectives - Implement funding schemes - Marketing and consumer education.
Lack of skilled personnel	- Provide training and education for EERTs project teams. - Time and market forces. - Share information and knowledge among industry practitioners.

Table 6-10 (*continued*): Measures to manage the critical risks of EERTs

Critical risks	Measures to manage the critical risks of EERTs
Low consumer demand and acceptance	- Encourage research and development on EERTs. - Marketing and consumer education. - Provide training and education for EERTs project teams. - Time and market forces.
Misplaced incentives	- Appoint independent commissioning agent. - Extended warranties by EERTs suppliers and contractors. - Implement energy performance contracting. - Implement funding schemes. - Involve asset managers during project design stage. - Tenant demand and involvement during project design stage.
Noise and building vibration	- Effective control strategy. - Implement mature and proven EERTs. - Provide suitable insulation. - Improve system design. - Encourage research and development on EERTs. - Marketing and consumer education.
Presence of system constraints	- Implement mature and proven EERTs. - Share information and knowledge among industry practitioners. - Move from an individual building basis into a whole environmental system basis - Provide training and education for EERTs project teams.
Slow response rate to temperature changes	- Effective control strategy. - Implement mature and proven EERTs. - Improve system design. - Marketing and consumer education.
Surface condensation and mould growth	- Improve system design. - Effective control strategy. - Provide suitable insulation. - Marketing and consumer education.
Uncertain availability of incentives	- Vote for a visionary and strong government. - Government should provide extra and adequate incentives. - Government should make definite policies with clear objectives. - Local authority should inform its clients of any available incentives.

Table 6-10 (*continued*): Measures to manage the critical risks of EERTs

Critical risks	Measures to manage the critical risks of EERTs
Uncertain government policies	- Be alert and up-to-date with EERTs market - Establish a contingency plan for EERTs. - Government should make definite policies with clear objectives. - Establish one system that addresses the different tools and models for green building accreditation. - Government needs to be ahead of the industry in awareness and information on EERTs. - Set policies that can be open for review in the future in set periods by the public and professionals. - Vote for a visionary and strong government.
Uncertain payback period	- Apply green leases. - Better feed-in tariff policies. - Implement energy performance contracting. - Implement funding schemes. - Marketing and consumer education. - Encourage research and development on EERTs. - Provide incentives for EERTs that reduce public infrastructure loads. - Implement mature and proven EERTs. - Use of judgmental decisions to align technology options with project objectives

6.4.6 Monitor and review

All steps of the risk management process should be scheduled for regular monitoring and review. For instance, the consequences and likelihoods of an event might change with time and this might lead to a change in the treatment options, making it essential to regularly repeat the risk management process (AS/NZS, 2004). Similarly, all predefined goals, objectives, scope, and parameters of the risk management process should also be monitored and reviewed. Furthermore, the five main goals of EERTs should also be subject to regular monitoring and review. In addition to monitoring and reviewing the risk management process on paper, there must be regular monitoring and review of the process on the ground. Inspectors should be assigned to verify that all steps and procedures approved on paper are implemented.

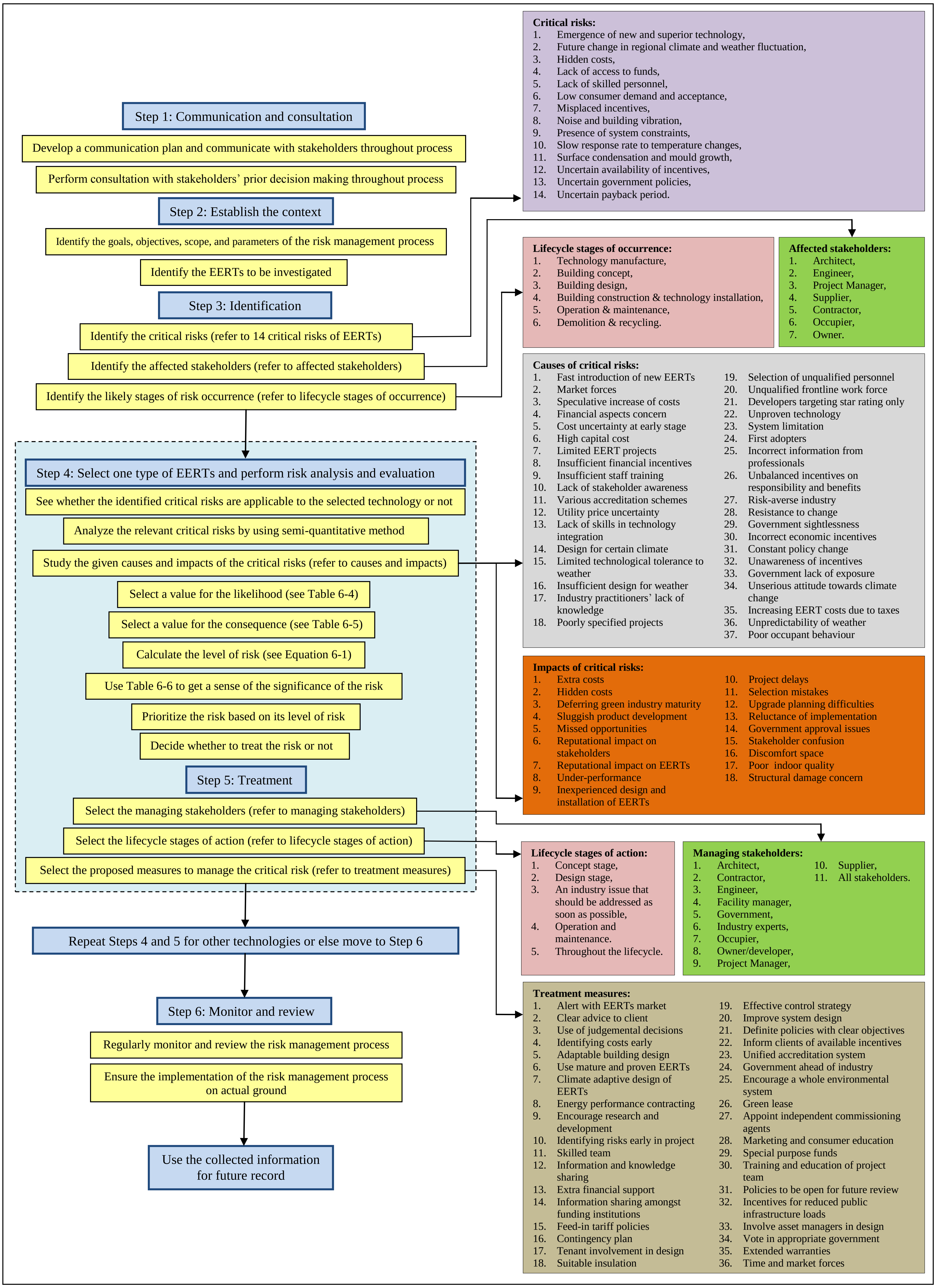

Figure 6-1: Critical risk management framework for the critical risks of Australian green office building EERTs

6.5 Case Studies and Framework Validation

The research framework was validated on two six star Green Star buildings certified by the GBCA. The first building is the Council House 2 (CH2) and the second building is the Pixel building, both located in Melbourne, Australia. The following sections will discusses each case study.

6.5.1 Council House 2 building

The Council House 2 (CH2) building is located in Melbourne's CBD. It is Australia's first building to be certified six stars (GBCA, 2011a). The 10 storey building with a total cost of $41.2 million was certified in 2005 and is expected to deliver a 10 year payback on the cost of its sustainability features (GBCA, 2011a).

The CH2 office building implements all of the nine EERTs covered in this research. This makes it the best candidate for the validation of the critical risk management framework of Australian green office building EERTs. The technologies implemented are: chilled beams, underfloor air distribution, radiant systems, night purge and natural ventilation, energy efficient light bulbs, motion sensors, photovoltaic panels, solar thermal system, and wind turbines. All technologies were evaluated as part of the framework validation process.

The CH2 project manager took part in the case study and provided the necessary feedback on the framework. Two sets of questions were directed to him. The first set included applying the framework to the technologies implemented in the CH2 building and asking him to provide comments on the proposed framework, as well as any additional information from his practical experience. The second sets of questions were related to the evaluation of the framework in terms of: 1. Clarity and ease of use, 2. Usefulness and effectiveness, 3. Comprehensiveness, and 4. Overall opinion of the framework.

The framework validation process started with applying the framework to the CH2 building and collecting comments on the proposed work. Table 6-11 presents the results of applying the framework to CH2 and the comments collected.

Table 6-11: Case study results

Framework step	Feedback
Communication and consultation	According to the CH2 project manager, the presented material for this step was found to be sufficient.
Establish the context	According to the CH2 project manager, the presented material for this step was found to be sufficient.
Identification	• *Chilled beams, radiant systems, underfloor air distribution, night purge and natural ventilation, photovoltaic panels, solar thermal systems, wind turbines:* According to the CH2 project manager, the information provided for the above EERTs, including the critical risks, affected stakeholders, and lifecycle stages of occurrence, were found to be appropriate. • *Energy efficient light bulbs:* For the critical risk *presence of system constraints,* it was found that the stakeholder affected is the occupier, and the lifecycle stage of occurrence is operation. • *Motion sensors:* For the critical risk *presence of system constraints,* it was found that the stakeholder affected is the occupier and the lifecycle stage of occurrence is operation.
Risk analysis and evaluation	• *Chilled beams, radiant systems, underfloor air distribution, solar thermal systems:* No critical risks identified in the context of CH2 for the EERTs above. • *Night purge and natural ventilation:* Two risks were identified: Future change in regional climate and weather fluctuation and slow response rate to temperature changes. 1. Analysis of the two previously selected critical risks was as follows: * Future change in regional climate and weather fluctuation, likelihood = 3, consequence = 2, level of risk = 6. * Slow response rate to temperature change, likelihood = 3, consequence = 2, level of risk = 6. 2. All risks require treatment as they have medium levels of risks. 3. Treatment prioritization was as follows: 1= Slow response rate to temperature changes, 2= Future change in regional climate and weather fluctuation. • *Energy efficient light bulbs:* One risk was identified, that is presence of system constraints. 1. Analysis was as follows: * Presence of system constraints, likelihood = 4, consequence = 3, level of risk = 12. 2. The risk requires treatment because it is of critical level of risk. • *Motion sensors:* One risk was identified, that is presence of system constraints. 1. Analysis was as follows: * Presences of system constraints, likelihood = 4, consequence = 3, level of risk = 12. 2. The risk requires treatment because it is of critical level of risk.

Table 6-11 (*continued*): Case study results

<table>
<tr><th>Framework step</th><th>Feedback</th></tr>
<tr><td>Risk analysis and evaluation (continued)</td><td>
• Photovoltaic panels:
One risk was identified, that is uncertain payback period.
1. Analysis was as follows:
* Uncertain payback period, likelihood = 3, consequence = 2, level of risk = 6.
2. The risk requires treatment because it is of medium level of risk.
• Wind turbines:
Four risks were selected as applicable to wind turbines: 1. Emergence of new and superior technology, 2. Future change in regional climate and weather fluctuation, 3. Lack of access to funds, and 4. Uncertain payback period.
1. Analysis of the four selected critical risks was as follows:
* Emergence of new and superior technology, likelihood = 4, consequence = 3, level of risk = 12.
* Future change in regional climate and weather fluctuation, likelihood = 3, consequence = 2, level of risk = 6.
* Lack of access to funds, likelihood = 4, consequence = 3, level of risk = 12.
* Uncertain payback period, likelihood = 4, consequence =3, level of risk = 12.
2. All risks require treatment as they have medium to critical levels of risks.
3. Treatment prioritization was as follows: 1=Uncertain payback period, 2=Emergence of new and superior technology, 3=Lack of access to funds, and 4=Future change in regional climate and weather fluctuation.
</td></tr>
<tr><td>Treatment</td><td>
• Chilled beams, radiant systems, underfloor air distribution, night purge and natural ventilation, photovoltaic panels, solar thermal systems:
According to the CH2 project manager, the presented managing measures for the EERTs above were found to be helpful and adequate.
• Energy efficient light bulbs and motion sensors:
To resolve the risk of presence of system constraints for both mentioned EERTs, the action taken by the building stakeholders was to appoint knowledgeable skilled personnel to re-implement and repair the technologies. This corresponds to the two proposed managing measures by the framework, which are: (1) Share information and knowledge among industry practitioners, and (2) Provide training and education for EERTs project teams. The building project manager also believed that the other managing measured provided in the framework are adequate and helpful.
• Wind turbines:
For the four critical risks identified, no managing measures were taken by the building stakeholders. The wind turbines were suspended from operation and discussion is carried on replacing them. The project manager reviewed the proposed managing measures provided in the framework and believed they are adequate and helpful specifically as pre-cautious measures for those projects which are still in concept and design stages.
</td></tr>
<tr><td>Monitor and review</td><td>According to the CH2 project manager, the presented material for this step was found to be sufficient.</td></tr>
</table>

The process of validation of the research framework included all six framework steps. Five of the framework steps did not require any changes or additions as the existing material was found to be sufficient. These steps are: communication and consultation, establish the context, risk analysis and evaluation, treatment, and monitor and review. The identification step was subject to changes or additions according to the context of CH2 building.

In the identification step, the CH2 project manager believed that the presented material for this step was sufficient except for two EERTs: energy efficient light bulbs and motion sensors. The project manager believed that for those two technologies with respect to the critical risk *presence of system constraints* the affected stakeholder is the occupier and the lifecycle stage of occurrence is operation and maintenance. This contradicts the findings of the questionnaire with the engineer being the affected stakeholder and the design stage being the lifecycle stage of risk occurrence. Clearly, the project manager expressed his views as a building occupier which influenced his opinion on this part. This explains the reason behind the different selection of affected stakeholders and lifecycle stages of occurrence.

In the risk analysis and evaluation step, the CH2 project manager analysed and evaluated the critical risks based on his experience in CH2. The results of this step show that four technologies were not subject to any critical risks in the context of CH2, these EERTs are: Chilled beams, radiant systems, underfloor air distribution, and solar thermal systems. The results of the other five are presented in Table 6-11.

During the case study interview, the CH2 project manager stated that the night purge and natural ventilation system is the best aspect of CH2. By this, the project manager validated the questionnaire findings of night purge and natural ventilation not having any critical risks and being a safe choice for stakeholders. The following statement was made:

> *"Night purge is probably the single best feature of the building"*

The project manager also highlighted the difficulties faced with the implementation of wind turbines on CH2 building. Issues such as indefinite payback, very high annual maintenance costs, and low energy generation due to area topography and weight of turbines, were encountered in CH2. This indicated that wind turbines were not mature enough for implementation, once again validating the questionnaire findings of wind turbine being likely to be affected by the highest number of critical risks among the selected EERTs.

Some recommendations were provided with regard to the framework. At the time of the case study, the tables of causes and impacts were presented in such a way that all causes or impacts were listed without reference to the corresponding critical risk. This has been changed in the final version of the thesis based on the following comment made by CH2 project manager:

> *"Causes and impacts table needs to be reformatted so the framework user can identify the specific causes or impacts that are relative to certain critical risks"*

CH2 project manager concluded that from his experience, having a single based location that contains renewable energy technologies that serves more than one property is better than having a separate system for each property. This validates the proposed measure M34 which exactly reflects to this comment. He provided the following statement:

> *"We found that it would be more efficient to put these technologies into a single base so instead of having a wind turbine for each building you will have those which are serving half a dozen building preferably close to each other and having the same owner, so you spread the costs over several buildings"*

After running the framework on the building, the CH2 project manager evaluated the framework using a Likert scale (see Table 6-12). The feedback on the characteristics of the framework is presented in Table 6-13.

Table 6-12: Likert scale

Likert level	Points
Strongly agree	5
Agree	4
Neither agree or disagree	3
Disagree	2
Strongly disagree	1

Table 6-13: Framework evaluation

Framework characteristics	Points
Clarity and ease of use	4
Usefulness and effectiveness	4
Comprehensiveness	5
Overall opinion	4

The framework scored very well. Three of the framework characteristics were given four points while comprehensiveness scored five points. This indicates the soundness of the framework design and content.

6.5.2 Pixel building

The second case study which also looks into validating the research framework was carried out on Pixel office building (GBCA, 2011c). The green office building is a 6 Star Green Star rating certified by the GBCA (GBCA, 2011c). It was certified in June of 2010 and achieved the highest ever green star score of 105 points (GBCA, 2011c). Innovative features are used throughout the building with an aim to motivate the sustainable building industry (GBCA, 2011c). The building has a gross floor area of approximately 1000 m^2 and is carbon natural during its construction and operation (GBCA, 2011c).

The Pixel building implements a total of seven EERTs covered in this research including: underfloor air distribution, radiant systems, night purge and natural ventilation, energy efficient light bulbs, motion sensors, photovoltaic panels, and wind turbines. All technologies were assessed as part of the framework validation process.

The Pixel ecologically sustainable development (ESD) engineer took part in the case study and provided the required information on the research framework. Similarly to CH2 office building, two sets of questions were directed to the building engineer, please refer to Appendix 12 for details. The validation process of Pixel office building was similar to the CH2 office building and all significant information collected are presented in Table 6-14.

Table 6-14: Case study results

<table>
<tr><th>Framework step</th><th>Feedback</th></tr>
<tr><td>Communication and consultation</td><td>According to the Pixel ESD engineer, the presented material for this step was found to be sufficient.</td></tr>
<tr><td>Establish the context</td><td>According to the Pixel ESD engineer, the presented material for this step was found to be sufficient.</td></tr>
<tr><td>Identification</td><td>• Radiant systems, night purge and natural ventilation, energy efficient light bulbs, motion sensors, wind turbines:
According to the CH2 project manager, the information provided for the above EERTs, including the critical risks, affected stakeholders, and lifecycle stages of occurrence, were found to be appropriate.
• Photovoltaic panels:
For the critical risk hidden costs, it was found that the stakeholder affected is the engineer.
• Underfloor air distribution:
For the critical risk presence of system constraints, it was found that the stakeholder affected is the contractor.</td></tr>
<tr><td>Risk analysis and evaluation</td><td>• Radiant systems, night purge and natural ventilation, energy efficient light bulbs, motion sensors:
No critical risks identified in the context of Pixel for the EERTs above.
• Underfloor air distribution:
Two risks were identified: Lack of skilled personnel and presence of system constraints.
4. Analysis of the two previously selected critical risks was as follows:
* Lack of skilled personnel, likelihood = 4, consequence = 4, level of risk = 16.
* Presence of system constraints, likelihood = 3, consequence = 2, level of risk = 6.
5. All risks require treatment as they have medium and critical levels of risks.
6. Treatment prioritization was as follows: 1 = Lack of skilled personnel, 2 = Presence of system constraints.
• Photovoltaic panels:
Five critical risks were identified: Emergence of new and superior technology, hidden costs, misplaced incentives, uncertain availability of incentives, and uncertain government policies.
3. Analysis was as follows:
* Emergence of new and superior technology, likelihood = 5, consequence = 3, level of risk = 15.
* Hidden costs, likelihood = 3, consequence = 2, level of risk = 6.
* Misplaced incentives, likelihood = 5, consequence = 3, level of risk = 15.
* Uncertain availability of incentives, likelihood = 4, consequence = 3, level of risk = 12.
* Uncertain government policies, likelihood = 4, consequence = 3, level of risk = 12.
4. All risks require treatment as they have medium and critical levels of risks.
5. Treatment prioritization was as follows: 1 = Emergence of new and superior technology, 2 = Misplaced incentives, 3 = Uncertain availability of incentives, 4 = Uncertain government policies, 5 = Hidden costs.</td></tr>
</table>

Table 6-14 (*continued*): Case study results

Framework step	Feedback
Risk analysis and evaluation (*continued*)	• *Wind turbines:* Six critical risks were identified: Emergence of new and superior technology, future change in regional climate and whether fluctuation, hidden costs, lack of skilled personnel, misplaced incentives, uncertain payback period. 3. Analysis was as follows: * Emergence of new and superior technology, likelihood = 4, consequence = 3, level of risk = 12. * Future change in regional climate and whether fluctuation, likelihood = 3, consequence = 3, level of risk = 9. * Hidden costs, likelihood = 3, consequence = 2, level of risk = 6. * Lack of skilled personnel, likelihood = 3, consequence = 4, level of risk = 12. * Misplaced incentives, likelihood = 4, consequence = 3, level of risk = 12. * Uncertain payback period, likelihood = 3, consequence = 2, level of risk = 6. 2. All risks require treatment as they have medium and critical levels of risks. 3. Treatment prioritization was as follows: 1 = Emergence of new and superior technology, 2 = Lack of skilled personnel, 3 = Misplaced incentives, 4 = Future change in regional climate and whether fluctuation, 5 = Hidden costs, 6 = Uncertain payback period.
Treatment	• *Radiant systems, night purge and natural ventilation, energy efficient light bulbs, motion sensors:* According to the Pixel ESD engineer, the presented managing measures for the EERTs above were found to be helpful and adequate. • *Underfloor air distribution* For resolving the critical risks lack of skilled personnel and presence of system constraints, the building stakeholders' reappointed people to carry on the job required. • *Photovoltaic panels:* • Similarly to the issues identified with the *underfloor air distribution system,* skilled personnel were hired to fix issues and perform the job required. • *Wind turbines:* Technical issues occurred with the wind turbines due to the lack of skilled personnel. The building stakeholders aim to resolve these technical issues by appointing skilled personnel.
Monitor and review	According to the Pixel ESD engineer, the presented material for this step was found to be sufficient.

All six steps of the framework were applied to Pixel building. It was found that five out of the six steps defined in the framework did not require any changes or additions as the existing material was found to be sufficient. These steps are: communication and consultation, establish the context, risk analysis and evaluation, and monitor and review. The framework step, identification was subject to minor changes according to the context of Pixel building.

In the identification step, the Pixel ESD engineer believes that with respect to photovoltaic panels it is the engineer rather than the owner that is the most affected stakeholder by the critical risk hidden costs. This opinion was made by the ESD engineer based on previous experience with such critical risks. Furthermore, with respect to underfloor air distribution systems, the ESD engineer believes that it is the contractor rather than the engineer that is the most affected stakeholders by the critical risk presence of system constraints. This opinion was also given based on previous experience with the pixel building.

The only major issue faced in the pixel building with EERTs is related to the implementation of the wind turbines. It seems that certain technical issues are preventing the wind turbines from generating the designed amount of energy. Although the wind turbines were tested before installation on the Pixel building with no issues, the source of technical issue is still unknown. The ESD engineer acknowledges the lack of skilled personnel in this field and strongly advises to invest in specialists.

At the end of the case study, the Pixel building ESD engineer evaluated the framework using a Likert scale (see Table 6-12). The feedback on the characteristics of the framework is presented in Table 6-15.

Table 6-15: Framework evaluation

Framework characteristics	Points
Clarity and ease of use	4
Usefulness and effectiveness	5
Comprehensiveness	4
Overall opinion	4

Similarly to CH2, the validation of the framework scored very well. Four points were given to three of the framework characteristics and five points was achieved for usefulness and effectiveness. This suggests the soundness of the framework design and content. Overall, the result of both case studies validates the research framework.

CHAPTER 7: CONCLUSION AND CONTRIBUTIONS

7.1 Introduction

This thesis started with the identification of the research questions and objectives which were presented in Chapter 1. An intensive literature review on the research topic was then presented in Chapter 2. This was followed with the establishment of the research methodology in Chapter 3 which illustrated how the research questions and objectives were approached in the research. Data analysis and findings of the questionnaire stage was presented in Chapter 4, where investigation was done on the identification of EERTs critical risks, exploration of differences in industry practitioners' opinion of risk, identification of affected stakeholders by risks, and identification of likely lifecycle stages of risk occurrence. Data analysis and findings of the interview stage was presented in Chapter 5, where managing approaches of EERTs critical risks were examined. The chapter covered the identification of causes, impacts, measures, managing stakeholders, and lifecycle stages of action against the critical risks of EERTs implemented in Australian green office buildings. In Chapter 6, a framework on the critical risk management for the implementation of EERTs in Australian green office buildings was presented with its guideline which was created based on the outcomes of the previous chapters. Additionally, Chapter 6 presents the outcomes of two case studies that served the purpose of validating the framework on two six star rated Australian green office buildings.

This chapter reports the conclusions of the research based on the outcomes of the previous chapters. It begins with the answers to the research objectives, followed the contributions of the study to the academic knowledge base in the field. The chapter then explains the benefits of Australian study to other countries, outlines the study limitations, and provides suggestions for future research, before closure.

7.2 Conclusions to Research Objectives

The research objectives were as follows:

1. Identify critical risks pertaining to the design, construction and throughout lifecycle of EERTs in Australian green office buildings.
2. Explore whether different industry expert groups have different perceptions f these risks.
3. Recognize the affected and responsible stakeholders of EERTs critical risks in the Australian green office buildings.
4. Classify the lifecycle stages at which the critical risks of green office buildings EERTs occur and the lifecycle stages of action against these critical risks.
5. Propose appropriate approaches to manage the critical risks identified.
6. Develop an integrated framework encapsulating critical risks and solutions to provide informed advice to stakeholders.

7.2.1 Objective 1

Risks of EERTs implemented in Australian green office buildings were not investigated sufficiently or comprehensively before, especially in the context of Australia. Chapter 2 reviewed and presented several literature sources that covered risks of EERTs, including risks that are categorised to be financial and market risks, technical risks, political and cultural risks, and environmental, health and safety risks. Nevertheless, identification of EERTs critical risks was not researched before in the context of Australian green office buildings. To achieve this research objective, a questionnaire was distributed among industry practitioners in the field of green buildings. The data collected were analysed and the findings were presented in Chapter 4. Based on the respondents' opinions EERTs are subject to 14 critical risks, with most affecting renewable energy technologies. Lighting technologies are not subject to any critical risks, indicating their safety compared to other EERTs. The respondents also indicate a general need for more funds and more stable policies with regard to EERTs.

7.2.2 Objective 2

Exploration of perception variation of the different industry practitioners groups on the risks of EERTs was done in order to study the position of each group from these risks and look for any significant differences. To achieve this objective, questionnaire data collected for the identification of EERTs critical risks were used. All EERTs are subject to different levels of risk perception among particular stakeholder groups, the exception of lighting technologies. All groups of industry practitioners who responded show higher concerns over the critical risk of *emergence of new superior technology* compared to engineers across several EERTs. This reflects the fact that engineers most often have the opportunity to select the EERTs to be implemented in green buildings and show their confidence in decisions-making relation to EERTs. In general, contractors show higher risk perception than other industry practitioners for all renewable energy technologies.

7.2.3 Objective 3

Identifying the affected stakeholders by the risks of EERTs and the stakeholders to manage the critical risks of EERTs was done to provide all stakeholders of EERTs with informed decision making based on the opinion of industry practitioners. To achieve this objective questionnaires and interviews were employed. The questionnaires were used to identify the stakeholders affected by EERTs risks while the interviews were used to identify the stakeholders for managing EERTs critical risks. The stakeholder most affected by EERTs risk is the owner followed by the occupier. Other stakeholders, including architects, engineers, project managers, suppliers, and contractors, are identified as being affected by a limited number of risks. Project managers and suppliers are each identified as least affected by EERTs risk. The interviews revealed that industry practitioners see engineers as the best stakeholders to manage all EERTs critical risks, with the exception of *misplaced incentives*. Following engineers for best management of EERTs critical risks are project managers.

7.2.4 Objective 4

In addition to the identification of affected and managing stakeholders, identification of the lifecycle stages at which risks are most likely to occur and the lifecycle stages of action against the risk was done. Similarly to objective 3, this was also executed to provide all stakeholders of EERTs with informed decision making based on the opinion of industry practitioners. To achieve this objective, questionnaires and interviews were employed. The questionnaires were used to identify the likely lifecycle stages of EERTs risk occurrence, while the interviews were used to identify the lifecycle stages of action against EERTs critical risks. The questionnaires revealed that the operation stage of the building and the technology is the most critical stage for EERTs, as most risks occur at this stage. The two lifecycle stages with the least risk occurrences are technology manufacturing and building construction and technology installation. The interviews showed that the design stage is the best lifecycle stage for taking action against the majority of EERTs critical risks, followed by the concept stage.

7.2.5 Objective 5

Subsequently to identifying EERTs critical risks, it is significant to set measures to manage these critical risks. To achieve this objective, interviews were and analysed to produce five essential features of EERTs critical risks: causes, impacts, measures, managing stakeholders, and lifecycle stages of action. The industry practitioners interviewed identified 37 causes, 18 impacts, and 36 managing measures for EERTs critical risks.

7.2.6 Objective 6

Last research objective was to incorporate all the research outcomes in one vehicle in the form of a framework and guide. This research framework will give informed advice to all EERTs stakeholders in relation to critical risks of EERTs implemented in Australian green office buildings and will help in reducing the risks of these buildings. The framework consists of six steps: 1. Communication and consultation, 2. Establish the context, 3. Identification, 4. Risk analysis and evaluation, 5. Treatment, and 6. Monitor and review. The framework is based on three well-established theories or models: the risk management process, stakeholder analysis, and the lifecycle asset management model. The research framework has been validated on two six star rated Australian green office buildings. The information provided by the framework has been shown to be very helpful in terms of the critical risks of EERTs. Furthermore, the evaluation of the framework was very good and the framework fulfils its purpose.

7.3 Contribution to Knowledge

To the author's knowledge, this research is the first to systematically explore the risks of EERTs implemented in Australian green office buildings. It has involved the use of several data collection methods including questionnaires, interviews, and two case studies, and professional green building industry practitioners played key roles in the study. The study makes a number of contributions to knowledge in the field, as follows:

- The researcher has identified the critical risks of EERTs implemented in Australian green office buildings. This enables those risks which are significant and require extra attention from EERTs stakeholders to be pin-pointed, giving a strong advantage to those who intend to become involved with EERTs whether or not they are experienced in the field of green buildings.
- The researcher has identified the stakeholders affected by the risks of EERTs as well as the stakeholders who are best able to manage the critical risks. This provides EERTs stakeholders with informed advice on their position in relation to EERTs risks, and enables them to be prepared to take action when required.
- Similarly, the researcher has identified the likely lifecycle stages of risk occurrence and the lifecycle stages of action against EERTs critical risks. This gives EERTs stakeholders informed advice on when EERTs risks are likely to occur and when to take precautions against those critical risks, even before the project starts.
- The research has identified measures to manage the critical risks of EERTs based on the opinions of industry practitioners. EERTs stakeholders will therefore be able to recognize solutions for the critical risks that they might encounter.

- Finally, the research framework developed acts as a map and a guide for all EERTs stakeholders concerned with these critical risks. The framework represents the major milestone of this research and it is the main contribution to knowledge.

7.4 Benefits of Australian Study to other Countries

The practice of green buildings is relatively new in Australia compared to other developed countries such as the United States of America and the United Kingdom, which poses many challenges for the stakeholders in this field. By revealing part of these challenges and developing the critical risk management framework for the Australian green office building, other countries that have similar or immature green building industry will benefit when embracing such existing work as they might face comparable challenges that maybe managed with equivalent solutions. Thus, the knowledge is transferred to other countries and possibly improved on its way which helps the green building industry reach maturity in a faster pace worldwide.

Several publications in the form of conference papers and journal articles were published or are in the process of being published. This will also assist in transferring the knowledge gained in the present research to other countries around the world.

7.5 Study Limitations

The study has four main limitations. The first limitation is related to the identification of EERTs risks from the literature review. Few authors have investigated the risks of EERTs, which made the process of identifying the risks difficult. For this reason, the literature review includes sources that cover general issues of EERTs as well as sources that cover issues of specific EERTs confined to the nine EERTs included in this research. During the questionnaire and interview stages, industry practitioners were asked to propose any risks other than the pre-identified 30 EERTs risks provided. However, none were proposed. Therefore, the original risk list is believed to be sufficient.

The second limitation is related to the groups of people who participated in the surveys. Both questionnaires and semi-structured interview questions were designed to seek for opinions from professionals in the field of green buildings with technical backgrounds. As a result, certain groups that didn't have the sufficient knowledge to participate in but are considered important stakeholders such as tenants were not approached. A separate questionnaire might be needed to capture their opinions on function and operation of EERTs.

The third limitation is related to the case studies and access to information. The author faced many challenges in identifying appropriate green office buildings for the validation of the framework as well as receiving the approval from the responsible authority for conducting the case studies.

The fourth limitation is related to the use of stakeholder analysis and lifecycle asset management. This research focuses on developing a critical risk management framework for EERTs implemented in Australian green office buildings. Knowledge of stakeholder analysis and lifecycle asset management was used to identify risk stakeholders as well as the likely stage of risk occurrence. Due to time limitations, the interaction of risk management between stakeholders and the time for controlling risk causes and executing the solutions to manage critical risks was not investigated.

7.6 Future Research

Several areas related to the present research present opportunities for future research. Following is a summary of these areas:

- One of the limitations of this research was the limited number of sources that identify the risks of EERTs implemented in green office buildings. A possible future study would be to further investigate the risks of EERTs implemented in green office buildings by site visits to green office buildings, interviewing stakeholders and conducting case studies with building operation and maintenance personnel.
- Similar research could be concluded to create a risk management framework for EERTs implemented in other types of buildings such as residential buildings. It would focus on EERTs that are more suitable for that type of building.
- Future research can be done on risk management for water technologies that are implemented in green buildings. During the interview stage of this research, many industry practitioners mentioned the existence of many risks for water technologies. This would be a fruitful area for future research.
- Similar research can be done in other countries whether these countries are considered mature or totally immature in the field of green building. Experience and knowledge on risk and risk management can be compared and shared among stakeholders.

7.7 Closure

This research began defining a problem that was apparent in the green building industry. It is hoped that this study has made a significant contribution to knowledge, particularly in the creation of the framework for EERTs critical risks. The study will be of interest to all stakeholders concerned with the identification of the critical risks, affected stakeholders, and lifecycle of occurrence. It will also assist with the management of critical risks by identifying management measures, managing stakeholders, and lifecycle stages of action. Thus, it will act as a guide for experienced and non-experienced stakeholders of EERTs implemented in Australian green office buildings.

Appendix 1 – Survey Questionnaire

The survey questionnaire was in an electronic format and will be presented similarly.

Section A: Demographic questions

Q1. What is your highest educational qualification?

Dropdown menu
Secondary School
Year 12 Certificate
TAFE / College Diploma
University - Undergraduate
University - Post-graduate
Other

Q2. Which occupation best describes your role in the building industry?

Dropdown menu
Architect
Engineer
Supplier
Contractor
Project Manager
Owner
Occupant

Q3. How many years of experience do you have in the above occupation?

Dropdown menu
1 – 5 years
6 – 10 years
11 – 15 years
More than 15 years

Q4. Which of the following energy efficient & renewable technologies have you installed or experienced in your home or workplace? (You can select more than one option)

□ Chilled beams	□ Radiant systems	□ Underfloor air distribution
□ Wind turbines	□ Motion sensors	□ Energy efficient light bulbs
□ Solar thermal systems	□ Photovoltaic panels	□ Night purge and natural ventilation

Q5. How many green building projects were you involved in?

Dropdown menu
None
Between 1 & 4
Between 5 & 10
More than 10

Section B: Evaluation of Risks associated with EERTs implemented in green office buildings

This section deals with the evaluation of the risks associated with the EERTs implemented in green office buildings classified according to their risk categories. It is divided into four main parts, which are HVAC, lighting, solar, and wind.

*Based on your knowledge and experience, **please answer the part/parts that you are familiar with** and indicate the **likelihood of occurrence** for these EERTs risk and its **impact on the stakeholders**. Please read each statement carefully.*

<u>Part 1: HVAC</u>

Q6. Please select the technology/technologies that you would like to comment on and evaluate its risks. You can add any risks that you believe should be considered in the designated space below.

☐ Chilled beams
☐ Radiant systems
☐ Underfloor air distribution
☐ Night purge and natural ventilation

Risks	Likelihood of occurrence	Impact on stakeholders
Aesthetically unpleasing	*Dropdown menu* Rare Unlikely Possible Likely Almost certain Not applicable	*Dropdown menu* Negligible Minor Moderate Major Severe Not applicable
CO_2 suffocation	*Dropdown menu*	*Dropdown menu*
Draught & thermal discomfort	*Dropdown menu*	*Dropdown menu*
Emergence of new and superior technology	*Dropdown menu*	*Dropdown menu*
Future change in regional climate and weather fluctuation	*Dropdown menu*	*Dropdown menu*
Hidden costs	*Dropdown menu*	*Dropdown menu*
Lack of access to funds	*Dropdown menu*	*Dropdown menu*
Lack of access to information about technology	*Dropdown menu*	*Dropdown menu*
Lack of access to spare parts	*Dropdown menu*	*Dropdown menu*
Lack of access to the technology	*Dropdown menu*	*Dropdown menu*
Lack of skilled personnel	*Dropdown menu*	*Dropdown menu*
Leakage of hazardous material	*Dropdown menu*	*Dropdown menu*
Low consumer demand and acceptance	*Dropdown menu*	*Dropdown menu*
Low product and performance reliability	*Dropdown menu*	*Dropdown menu*

Misplaced incentives	*Dropdown menu*	*Dropdown menu*
Operational failure	*Dropdown menu*	*Dropdown menu*
Presence of system constraints	*Dropdown menu*	*Dropdown menu*
Slow response rate to temperature changes	*Dropdown menu*	*Dropdown menu*
Surface condensation and mould growth	*Dropdown menu*	*Dropdown menu*
Unauthorized building entrance	*Dropdown menu*	*Dropdown menu*
Uncertain availability of incentives	*Dropdown menu*	*Dropdown menu*
Uncertain payback period	*Dropdown menu*	*Dropdown menu*

Q7. If you have any extra risks that you would like to add, please use the following space:

Part 2: Lighting

Q8. Please select the technology/technologies that you would like to comment on and evaluate its risks. You can add any risks that you believe should be considered in the designated space below.

□ Motion sensors

□ Energy efficient light bulbs

Risks	Likelihood of occurrence	Impact on stakeholders
Aesthetically unpleasing	*Dropdown menu* Rare Unlikely Possible Likely Almost certain Not applicable	*Dropdown menu* Negligible Minor Moderate Major Severe Not applicable
Emergence of new and superior technology	*Dropdown menu*	*Dropdown menu*
Headaches and skin rash	*Dropdown menu*	*Dropdown menu*
Hidden costs	*Dropdown menu*	*Dropdown menu*
Lack of access to funds	*Dropdown menu*	*Dropdown menu*
Lack of access to information about technology	*Dropdown menu*	*Dropdown menu*
Lack of access to spare parts	*Dropdown menu*	*Dropdown menu*
Lack of access to the technology	*Dropdown menu*	*Dropdown menu*
Lack of skilled personnel	*Dropdown menu*	*Dropdown menu*
Leakage of hazardous material	*Dropdown menu*	*Dropdown menu*
Low consumer demand and acceptance	*Dropdown menu*	*Dropdown menu*
Low product and performance reliability	*Dropdown menu*	*Dropdown menu*
Misplaced incentives	*Dropdown menu*	*Dropdown menu*
Operational failure	*Dropdown menu*	*Dropdown menu*
Presence of system constraints	*Dropdown menu*	*Dropdown menu*
Uncertain payback period	*Dropdown menu*	*Dropdown menu*

Q9. If you have any extra risks that you would like to add, please use the following space:

Part 3: Solar

Q10. Please select the technology/technologies that you would like to comment on and evaluate its risks. You can add any risks that you believe should be considered in the designated space below.

□ Solar thermal systems □ Photovoltaic panels

Risks	**Likelihood of occurrence**	**Impact on stakeholders**
Aesthetically unpleasing	*Dropdown menu* Rare Unlikely Possible Likely Almost certain Not applicable	*Dropdown menu* Negligible Minor Moderate Major Severe Not applicable
Dangerous emissions from unit production	*Dropdown menu*	*Dropdown menu*
Emergence of new and superior technology	*Dropdown menu*	*Dropdown menu*
Fire risk	*Dropdown menu*	*Dropdown menu*
Future change in regional climate and weather fluctuation	*Dropdown menu*	*Dropdown menu*
Glare risk from collector sunlight reflection	*Dropdown menu*	*Dropdown menu*
Hidden costs	*Dropdown menu*	*Dropdown menu*
Lack of access to funds	*Dropdown menu*	*Dropdown menu*

Lack of access to information about technology	*Dropdown menu*	*Dropdown menu*
Lack of access to spare parts	*Dropdown menu*	*Dropdown menu*
Lack of access to the technology	*Dropdown menu*	*Dropdown menu*
Lack of skilled personnel	*Dropdown menu*	*Dropdown menu*
Leakage of hazardous material	*Dropdown menu*	*Dropdown menu*
Low consumer demand and acceptance	*Dropdown menu*	*Dropdown menu*
Low product and performance reliability	*Dropdown menu*	*Dropdown menu*
Misplaced incentives	*Dropdown menu*	*Dropdown menu*
Operational failure	*Dropdown menu*	*Dropdown menu*
Physical degradation	*Dropdown menu*	*Dropdown menu*
Presence of system constraints	*Dropdown menu*	*Dropdown menu*
Uncertain availability of incentives	*Dropdown menu*	*Dropdown menu*
Uncertain government policies	*Dropdown menu*	*Dropdown menu*
Uncertain payback period	*Dropdown menu*	*Dropdown menu*

Q11. If you have any extra risks that you would like to add, please use the following space:

Part 4: Wind

Q12. The only technology involved in this part is wind turbines, please consider when making your evaluation. You can add any risks that you believe should be considered in the designated space below.

Risks	**Likelihood of occurrence**	**Impact on stakeholders**
Aesthetically unpleasing	*Dropdown menu* Rare Unlikely Possible Likely Almost certain Not applicable	*Dropdown menu* Negligible Minor Moderate Major Severe Not applicable
Bird collision	*Dropdown menu*	*Dropdown menu*
Emergence of new and superior technology	*Dropdown menu*	*Dropdown menu*
Future change in regional climate and weather fluctuation	*Dropdown menu*	*Dropdown menu*
Hidden costs	*Dropdown menu*	*Dropdown menu*
Lack of access to funds	*Dropdown menu*	*Dropdown menu*
Lack of access to information about technology	*Dropdown menu*	*Dropdown menu*
Lack of access to spare parts	*Dropdown menu*	*Dropdown menu*
Lack of access to the technology	*Dropdown menu*	*Dropdown menu*
Lack of skilled personnel	*Dropdown menu*	*Dropdown menu*
Low consumer demand and acceptance	*Dropdown menu*	*Dropdown menu*
Low product and performance reliability	*Dropdown menu*	*Dropdown menu*

Misplaced incentives	*Dropdown menu*	*Dropdown menu*
Noise and building vibration	*Dropdown menu*	*Dropdown menu*
Operational failure	*Dropdown menu*	*Dropdown menu*
Presence of system constraints	*Dropdown menu*	*Dropdown menu*
Uncertain availability of incentives	*Dropdown menu*	*Dropdown menu*
Uncertain government policies	*Dropdown menu*	*Dropdown menu*
Uncertain payback period	*Dropdown menu*	*Dropdown menu*

Q13. If you have any extra risks that you would like to add, please use the following space:

Section C: Stakeholders & lifecycle stages associated with the risks of EERTs implemented in green office buildings

<u>Part 1: Stakeholders</u>

Q14. This question aims to identify the stakeholders affected by the risks associated with the EERTs implemented in green office buildings. Based on your knowledge and experience, please select the most affected stakeholders as. Please read each statement carefully, you may select more than one option in this section.

Please note that the risk list below is comprehensive and includes risks from all four technology categories.

Risk	Architect	Engineer	Project Manager	Supplier	Contractor	Occupier	Owner
Uncertain payback period	☐	☐	☐	☐	☐	☐	☐
Lack of access to fund	☐	☐	☐	☐	☐	☐	☐
Hidden costs	☐	☐	☐	☐	☐	☐	☐
Lack of access to information about technology	☐	☐	☐	☐	☐	☐	☐
Low product and performance reliability	☐	☐	☐	☐	☐	☐	☐
Lack of skilled personnel	☐	☐	☐	☐	☐	☐	☐
Presence of system constraints	☐	☐	☐	☐	☐	☐	☐
Low consumer demand and acceptance	☐	☐	☐	☐	☐	☐	☐
Lack of access to technology	☐	☐	☐	☐	☐	☐	☐
Lack of access to spare parts	☐	☐	☐	☐	☐	☐	☐
Emergence of new and superior technology	☐	☐	☐	☐	☐	☐	☐
Operational failure	☐	☐	☐	☐	☐	☐	☐
Misplace incentives	☐	☐	☐	☐	☐	☐	☐
Aesthetically unpleasing	☐	☐	☐	☐	☐	☐	☐
HVAC, Solar, Wind: Future change in regional climate and weather fluctuation	☐	☐	☐	☐	☐	☐	☐
HVAC, Solar, Wind: Uncertain availability of incentives	☐	☐	☐	☐	☐	☐	☐
HVAC, Lighting, Solar: Leakage of hazardous material	☐	☐	☐	☐	☐	☐	☐
Solar: Fire risk	☐	☐	☐	☐	☐	☐	☐

(*continued*):

Risk	Architect	Engineer	Project Manager	Supplier	Contractor	Occupier	Owner
Solar: Physical degradation	□	□	□	□	□	□	□
Solar, Wind: Uncertain government policies	□	□	□	□	□	□	□
HVAC: Slow response rate to temperature changes	□	□	□	□	□	□	□
HVAC: Drought and thermal discomfort	□	□	□	□	□	□	□
HVAC: Unauthorized building entrance	□	□	□	□	□	□	□
HVAC: Surface condensation and mould growth	□	□	□	□	□	□	□
HVAC: CO_2 Suffocation	□	□	□	□	□	□	□
Lighting: Headaches and skin rash	□	□	□	□	□	□	□
Solar: Glare risk from collector sunlight reflection	□	□	□	□	□	□	□
Solar: Dangerous emissions from unit production	□	□	□	□	□	□	□
Wind: Noise and building vibration	□	□	□	□	□	□	□
Wind: Bird collision	□	□	□	□	□	□	□

Part 2: Lifecycle stages

Q15. This question aims to identify the lifecycle phase at which the risks of EERTs might occur. Based on your knowledge and experience, please the most likely stages at which these EERTs risks might occur. Please read each statement carefully, you may select more than one option in this section.

Please note that the risk list below is comprehensive and includes risks from all four technology categories.

Risk	Technology manufacturing	Building concept	Building design	Building construction & technology installation	Operation & maintenance	Demolition & recycling
Uncertain payback period	◻	◻	◻	◻	◻	◻
Lack of access to fund	◻	◻	◻	◻	◻	◻
Hidden costs	◻	◻	◻	◻	◻	◻
Lack of access to information about technology	◻	◻	◻	◻	◻	◻
Low product and performance reliability	◻	◻	◻	◻	◻	◻
Lack of skilled personnel	◻	◻	◻	◻	◻	◻
Presence of system constraints	◻	◻	◻	◻	◻	◻
Low consumer demand and acceptance	◻	◻	◻	◻	◻	◻
Lack of access to technology	◻	◻	◻	◻	◻	◻
Lack of access to spare parts	◻	◻	◻	◻	◻	◻
Emergence of new and superior technology	◻	◻	◻	◻	◻	◻
Operational failure	◻	◻	◻	◻	◻	◻
Misplace incentives	◻	◻	◻	◻	◻	◻
Aesthetically unpleasing	◻	◻	◻	◻	◻	◻
HVAC, Solar, Wind: Future change in regional climate and weather fluctuation	◻	◻	◻	◻	◻	◻
HVAC, Solar, Wind: Uncertain availability of incentives	◻	◻	◻	◻	◻	◻

(*continued*):

Risk	Technology manufacturing	Building concept	Building design	Building construction & technology installation	Operation & maintenance	Demolition & recycling
HVAC, Lighting, Solar: Leakage of hazardous material	◻	◻	◻	◻	◻	◻
Solar: Fire risk	◻	◻	◻	◻	◻	◻
Solar: Physical degradation	◻	◻	◻	◻	◻	◻
Solar, Wind: Uncertain government policies	◻	◻	◻	◻	◻	◻
HVAC: Slow response rate to temperature changes	◻	◻	◻	◻	◻	◻
HVAC: Drought and thermal discomfort	◻	◻	◻	◻	◻	◻
HVAC: Unauthorized building entrance	◻	◻	◻	◻	◻	◻
HVAC: Surface condensation and mould growth	◻	◻	◻	◻	◻	◻
HVAC: CO_2 Suffocation	◻	◻	◻	◻	◻	◻
Lighting: Headaches and skin rash	◻	◻	◻	◻	◻	◻
Solar: Glare risk from collector sunlight reflection	◻	◻	◻	◻	◻	◻
Solar: Dangerous emissions from unit production	◻	◻	◻	◻	◻	◻
Wind: Noise and building vibration	◻	◻	◻	◻	◻	◻
Wind: Bird collision	◻	◻	◻	◻	◻	◻

Q16. Please use the space below for any comments on the questionnaire:

Appendix 2 – Results of Questionnaire Data Analysis: Risks of EERTs with Mean Risk Impact Values

Risk	**HVAC**		**Lighting**			**Solar**		**Wind**	
	CB	NV	RS	UFAD	EELB	MS	ST	PV	WT
Aesthetically unpleasing	6.98	5.83	6.5	5.88	7.03	5.26	8.08	7.46	9.36
Bird collision									6.65
CO_2 suffocation	4.6		3.83						
Dangerous emissions from unit production							5.18	5.93	
Draught & thermal discomfort	7.12	8.08	6.6	6.94					
Emergence of new and superior technology	7.76		7.8	6.84	8.14	7.17	11	11.73	10.24
Fire risk							4.9	4.54	
Future change in regional climate and weather fluctuation	5.83	7.96	6.37	5.27			8.2	10.19	10.42
Glare risk from collector sunlight reflection							6.7	6.93	
Headaches and skin rash					3.51				
Hidden costs	9.16	7.87	10.18	9.37	3.69	4.49	9.38	9.77	11.11
Lack of access to funds	11.57	9.42	12.20	10.59	4.41	5.65	12.75	13.31	12.87
Lack of access to information about technology	7.05	6.04	6.97	7.14	3.4	3.8	7.95	8.18	8.64
Lack of access to spare parts	6.69		6.6	6.08		4.14	8	7.01	9.58
Lack of access to the technology	4.97	4.70	5.53	4.84	3.14	3.55	6.88	5.85	8.78
Lack of skilled personnel	8.38	7.48	10.17	9.33		4.52	8.98	8.39	10.05
Leakage of hazardous material			8.23		4.19		5.15		
Low consumer demand and acceptance	8.62	8.98	10.53	9.04	5.21	5.28	9.33	8.32	9.36
Low product and performance reliability	8.17	7.69	7.37	8.33	4.97	6.06	8.87	9.14	9.78
Misplaced incentives	7.74	7.25	9.03	6.84	5.92	5.02	11.58	10.56	10.09
Noise and building vibration									10.87
Operational failure	8.86	8.48	8.83	7.76	6.4	7.29	8.18	8.3	9.62
Physical degradation							8.8	8.77	
Presence of system constraints	10.78	8.94	10.83	10.24	5.24	5.42	10.53	10.58	11.25
Slow response rate to temperature changes			10.19						
Surface condensation and mould growth	10.14	7.75	8.73	7.73					
Unauthorized building entrance		6.06							
Uncertain availability of incentives	7.97	6.85	7.9	7.29			14.08	13.85	11.89
Uncertain government policies							14.35	13.85	12.13
Uncertain payback period	9.07	8.58	10.77	8.51	4.38	5.54	11.58	12.82	13.09

Appendix 3 – Results of Questionnaire Data Analysis: Comparison of Industry Practitioners Risk Perception

Technology	Risk	Stakeholder with higher risk perception (A)	Stakeholder with lower risk perception (B)	Mean Difference (A - B)	Significance
CB	Emergence of new and superior technology	Architect	Engineer	5.686	0.002
NV	Uncertain payback period	Engineer	Architect	4.442	0.028
	Low consumer demand and acceptance	Project Manager	Architect	7.642	0.012
PV	Uncertain payback period	Contractor	Project Manager	8.306	0.006
	Hidden costs	Contractor	Project Manager	6.014	0.038
	Lack of access to information about technology	Contractor	Engineer	6.567	0.003
	Lack of skilled personnel	Project Manager	Engineer	2.964	0.042
	Lack of access to the technology	Contractor	Architect	5.611	0.018
		Contractor	Engineer	5.290	0.017
	Emergence of new and superior technology	Project Manager	Engineer	5.268	0.018
	Physical degradation	Contractor	Architect	5.222	0.039
		Contractor	Project Manager	5.375	0.037
RS	Misplaced incentives	Contractor	Architect	9.524	0.036
		Contractor	Engineer	10.137	0.011
ST	Emergence of new and superior technology	Contractor	Engineer	8.461	0.006
UFAD	Lack of access to necessary spare parts	Engineer	Contractor	2.985	0.012
		Project Manager	Contractor	6.436	0.017
	Emergence of new and superior technology	Architect	Engineer	4.722	0.035
WT	Lack of skilled personnel	Contractor	Engineer	7.357	0.039
		Contractor	Architect	7.850	0.036

Appendix 4 – Results of Questionnaire Data Analysis: Full Results of Affected Stakeholders by EERTs Risks Identification

Risk	SAR value						
	Architect	**Engineer**	**Project Manager**	**Supplier**	**Contractor**	**Occupier**	**Owner**
Aesthetically unpleasing	*9.8*	-5.7	-5.5	-6.1	-6.6	*6.5*	*7.6*
Bird collision	-1.4	-1.6	-2.9	-4.7	-3.9	*6.8*	*7.8*
CO_2 suffocation	-3.6	1.5	-4.3	-4	-3.2	*8.7*	*4.9*
Dangerous emissions from unit production	-3.6	-0.3	-3.9	0.2	-3.6	*6.6*	*4.7*
Draught & thermal discomfort	-3.5	0.7	-4.4	-4.4	-3	*10.9*	*3.8*
Emergence of new and superior technology	-1.1	*3.1*	-4.1	0.5	-3	-2.6	*7.2*
Fire risk	-4	-0.5	-4.2	-3.8	-2	*6.7*	*7.8*
Future change in regional climate and weather fluctuation	-3.3	*3.6*	-3.8	-2.6	-4.9	*4.7*	*6.3*
Glare risk from collector sunlight reflection	0.5	0.8	-4.8	-5.3	-5.5	*8.7*	*5.7*
Headaches and skin rash	-3.4	-1.1	-4.8	-4.1	-4.3	*12.5*	*5.1*
Hidden costs	-5.1	-3.2	0.5	-5.1	-0.8	0.3	*13.5*
Lack of access to funds	-2.9	-2.4	-0.2	-2.4	-4	-3.1	*15.1*
Lack of access to information about technology	*4.3*	*8.8*	-2.6	-5.1	-1.4	-5.1	1.1
Lack of access to spare parts	-6.6	-3.8	-4.4	1.3	*6.1*	0.4	*7*
Lack of access to the technology	-0.2	*4.3*	-1.6	0	*3*	-5.2	-0.2
Lack of skilled personnel	-4.1	-1.6	*2.4*	-2.2	*9.8*	-5.2	0.9
Leakage of hazardous material	-4.4	-1.2	-4.6	-2.5	-0.3	*7.1*	*6*
Low consumer demand and acceptance	0.6	-1	-3.3	*2.4*	-3.3	-0.5	*5.1*
Low product and performance reliability	-4.7	0.4	-5.1	-1.7	-1.5	*4.5*	*8.1*
Misplaced incentives	-2.7	-2.9	-2.4	-1.7	-3.4	0.4	*12.7*
Noise & building vibration	-3.6	1.8	-3.9	-5.2	-3.9	*8.8*	*6*
Operational failure	-6.9	-2.8	-4.9	-2.2	*2.8*	*6.1*	*7.8*
Physical degradation	-3.1	-0.6	-5	-1.7	-2.4	*3.1*	*9.8*
Presence of system constraints	0.4	*7.1*	-1.5	-4.6	-0.2	-2.3	1
Slow response to temperature changes	-3.9	1.1	-4.8	-3.7	-3.7	*10.2*	*4.7*
Surface condensation and mould growth	-4.1	1.2	-5.4	-4.7	-1.7	*7.5*	*7.3*
Unauthorized building entrance	-1.5	-3.2	-3.2	-4.5	-3.5	*9.1*	*6.9*
Uncertain availability of incentives	-3.4	-3.2	-3	-1.8	-3.9	0.1	*15.2*
Uncertain government policies	-2.6	-1.2	-3.1	-1.9	-3.3	1.1	*11.2*
Uncertain payback period	-3.2	-1.6	-0.9	-4.9	-5.8	0.4	*16*

Appendix 5 – Results of Questionnaire Data Analysis: Full Results of Technology or Building Lifecycle Stages at which EERTs Risks Might Occur

Risk	SAR value					
	Manufacturing	Concept	Design	Constriction	Operation	Demolition
Aesthetically unpleasing	-3.9	*5.6*	*7.5*	-2	-1.3	-6
Bird collision	-3.5	-1.8	-1.2	-2.6	*12.6*	-3.5
CO_2 suffocation	-2.9	-3.7	-0.3	-1.9	*12.6*	-3.7
Draught & thermal discomfort	-3.4	-2	0.4	-2.6	*12.1*	-4.4
Emergence of new and superior technology	1.4	1.6	1.6	-2.3	1.1	-3.4
Fire risk	-2.1	-3.3	0.1	-2.3	*11*	-3.3
Future change in regional climate and whether fluctuation	-1.1	-0.8	1.2	-2.6	*7.4*	-4.1
Glare risk from collector sunlight reflection	-3.5	-0.3	1	-2.4	*9.4*	-4.2
Headaches and skin rash	-2.5	-3	-0.8	-3.6	*12.9*	-3
Hidden costs	-4.6	-3.2	-0.6	*5.7*	*6.6*	-3.9
Lack of access to funds	-1.9	*7.5*	*3.5*	0.7	-3.6	-6.2
Lack of access to information about technology	-0.7	*3.5*	*7.6*	-0.5	-3.4	-6.5
Lack of access to spare parts	-0.8	-3.8	-3.6	-0.3	*13.4*	-4.8
Lack of access to the technology	*2.6*	*2.2*	*3.3*	1.5	-3	-6.6
Lack of skilled personnel	-3	-4.3	-1.3	*8.5*	*5*	-5
Leakage of hazardous material	-2.2	-3.4	-3.2	-1.7	*9.8*	0.7
Low consumer demand and acceptance	1	*5.5*	*2.3*	-3.9	0.3	-5.2
Low product and performance reliability	-1.6	-4.2	-2.6	0.6	*13.2*	-5.4
Misplaced incentives	-0.6	*3.6*	1.6	0.2	0.4	-5.2
Noise & building vibration	-2.6	-2.6	-0.3	-0.8	*10.8*	-4.5
Operational failure	-3.6	-4.6	-4.6	-1.2	*16.8*	-2.8
Physical degradation	-2.1	-3.9	-2.3	-3.1	*13.1*	-1.5
Presence of system constraints	-3.3	*2.8*	*8.2*	0.1	-1.1	-6.7
Slow response rate to temperature changes	-2	-2.3	1.3	-2.8	*10.7*	-4.9
Surface condensation and mould growth	-3.2	-3.7	-1.1	-1.6	*12.3*	-2.7
Unauthorized building entrance	-4.1	-3.2	-1.4	-0.5	*12.8*	-3.5
Uncertain availability of incentives	-0.2	*2.7*	0.5	-1.2	*2.2*	-4.1
Uncertain government policies	0.4	*2.8*	1.6	-2.3	1.9	-4.5
Uncertain payback period	-2.2	*4.5*	*3.1*	-3.4	*3.4*	-5.4

Appendix 6 – Survey Interview

Critical Risks identified for EERTs:

1. Emergence of new and superior technology,
2. Future change in regional climate and weather fluctuation.
3. Hidden costs,
4. Lack of access to funds,
5. Lack of skilled personnel,
6. Low consumer demand and acceptance, in the case of radiant cooling/heating systems
7. Misplaced incentives,
8. Noise and building vibration, in the case of wind turbines
9. Presence of technical constraints,
10. Slow response rate to temperature changes, in the case of radiant cooling/heating systems
11. Surface condensation and mould growth, in the case of chilled beam systems
12. Uncertain availability of incentives,
13. Uncertain government policies,
14. Uncertain payback periods,

Q) For each of the previously mentioned critical risks, can you please answer the following:

1. What are the causes of this critical risk?
2. What are the impacts of this critical risk on the stakeholders?
3. What are the solutions for this critical risk? <u>(Please give more details to the answer of this question)</u>
4. Who are the stakeholders to manage this critical risk and when is the best time to manage this critical risk during the technology or building lifecycles?

Appendix 7 – Results of Interview Data Analysis: Causes of EERTs Critical Risks

Code	Causes of the critical risks of EERTs	Abridged names
C1	The introduction of new more effective EERTs at a fast pace making previous versions redundant.	Fast introduction of new EERTs
C2	Market forces and innovation.	Market forces
C3	Suppliers and contractors increasing their costs as soon as they know that potential owners of EERTs are seeking them for reasons apart from financial costs.	Speculative increase of costs
C4	Clients and developers mostly concerned with financial aspects of EERTs and not considering other aspects such as environment, marketing and quality.	Financial aspects concern
C5	Not recognizing EERTs' cost at early stages of project.	Cost uncertainty at early stage
C6	High capital cost.	High capital cost
C7	Limited number of projects incorporating EERTs.	Limited EERT projects
C8	Insufficient financial incentives for industry practitioners to become skilled with EERTs.	Insufficient financial incentives
C9	Companies' failure to provide sufficient support to invest in staff training.	Insufficient staff training
C10	Lack of information and awareness among EERT stakeholders.	Lack of stakeholder awareness
C11	Existence of different schemes, models, and tools for green building accreditation.	Various accreditation schemes
C12	Uncertainty in the prediction of future electricity and water prices.	Utility price uncertainty
C13	Industry practitioners do not have a holistic view, as most practitioners are only knowledgeable in their own field of practice.	Lack of skills in technology integration
C14	The design of EERTs specifically for certain climate profiles, leading to difficulties for these technologies to react to weather fluctuation and climate change.	Design for certain climate
C15	New technologies in general have less capacity and fewer safety factors in design compared to old technologies making them more susceptible to weather fluctuation and climate change.	Limited technological tolerance to weather
C16	Professionals selecting EERTs not considering sufficient timeframes for weather cycles.	Insufficient design for weather
C17	Lack of knowledge, education and training among industry practitioners.	Industry practitioners' lack of knowledge
C18	Poorly specified projects and unsuitable contract conditions.	Poorly specified projects
C19	The selection of unqualified people for jobs involving EERTs.	Selection of unqualified people
C20	Personnel on the top of the pyramid are well educated on EERTs but the issue affects personnel on the bottom of the pyramid.	Unqualified frontline workforce
C21	Developers installing EERTs in order to acquire a green building rating without taking into account the soundness or quality of these technologies.	Developers targeting star rating only
C22	Unproven technology.	Unproven technology
C23	System limitation.	System limitation
C24	Being one of first adopters without having sufficient experience.	First adopters

Appendix 7 (*continued*) - Results of Interview Data Analysis: Causes of EERTs Critical Risks

Code	Causes of the critical risks of EERTs	Abridged names
C25	Green building council, suppliers and people promoting the use of EERTs providing the public with incorrect information.	Incorrect information from professionals
C26	Developers or clients not interested to invest in technologies that do not have instant results, especially when the developer or owner does not have to deal with ongoing costs.	Unbalanced incentives on responsibility and benefits
C27	Consulting industry in Australia very risk-averse.	Risk-averse industry
C28	Resistance to change.	Resistance to change
C29	Government not dedicating sufficient time to policies related to EERTs and sightlessness.	Government sightlessness
C30	Government not offering the right economic incentives for EERTs and being cautious in providing funding.	Incorrect economic incentives
C31	Constant policy changes and no clear goals.	Constant policy changes
C32	Stakeholders not being aware of accessible incentives or how to claim them.	Unawareness of incentives
C33	Government lacking understanding and exposure to EERTs.	Government lack of exposure
C34	Government not taking climate change seriously.	Unserious attitude towards climate change
C35	Taxes imposed by government increasing costs of EERTs.	Increasing costs due to taxes
C36	The unpredictability of weather.	Unpredictability of weather
C37	Poor occupant behaviour.	Poor occupant behaviour

Appendix 8 – Results of Interview Data Analysis: Impacts of EERTs Critical Risks

Code	Impacts of the critical risks of EERTs	Abridged names
I1	Extra financial costs.	Extra costs
I2	Project is subjected to hidden costs.	Hidden costs
I3	Slows the rate at which green industry progresses to maturity.	Deferring green industry maturity
I4	No or slow product development, which can keep prices of technology high.	Sluggish product development
I5	Manufacturers missing out on opportunities due to low user demand.	Missed opportunities
I6	Reputational impact on stakeholders.	Reputational impact on stakeholders
I7	Reputational impact on EERTs.	Reputational impact on EERTs
I8	Technology's under-performance or failure.	Under-performance
I9	Inexperienced design and installation of EERTs due to lack of knowledge accumulated in real applications.	Inexperienced design and installation of EERTs
I10	Delays in project.	Project delays
I11	Best available systems in terms of lifecycle performance not being selected.	Selection mistakes
I12	Difficulty in making decision and planning for the future technology upgrade or building retrofit.	Upgrade planning difficulties
I13	Reluctance of EERT implementation.	Reluctance of implementation
I14	EERTs not being approved by government agencies.	Government approval issues
I15	Confusion as EERT stakeholders do not know where to position themselves in terms of proceeding with green building projects	Stakeholder confusion
I16	Discomfort occupancy space.	Discomfort space
I17	Poor indoor environment quality.	Poor indoor quality
I18	Potential damage to building structure.	Structural damage concern

Appendix 9 – Results of Interview Data Analysis: Managing Measures of EERTs Critical Risks

Code	Measures to manage the critical risks of EERTs	Abridged names
M1	Being alert and up-to-date with EERTs market.	Alert with EERTs market
M2	Provide clear advice to the client on the advantages and disadvantages of accessible EERTs.	Clear advice to client
M3	Use of judgmental decisions to align technology options with project objectives and identify the objectives early in the project life.	Use of judgemental decisions
M4	Identifying the costs at an early stage of the project life.	Identifying costs early
M5	Design buildings so they can be adaptable for future EERTs.	Adaptable building design
M6	Implement mature and proven EERTs.	Use mature and proven EERTs
M7	Consider long-term climate cycles in the selection and design of EERTs.	Climate adaptive design of EERTs
M8	Implement energy performance contracting.	Energy performance contracting
M9	Encourage research and development on EERTs.	Encourage research and development
M10	Give more focus on identifying risks comprehensively at early in project life.	Identifying risks early in project
M11	Have experienced and skilled industry practitioners on the team.	Skilled team
M12	Share information and knowledge among industry practitioners.	Information and knowledge sharing
M13	Provide training and education for EERT project teams.	Training and education of project team
M14	Better knowledge and more information sharing amongst the funding institutions with encouragement to lend money to developers or owners if they undertake to deliver green buildings.	Information sharing amongst funding institutions
M15	Appoint independent commissioning agents.	Appoint independent commissioning agents
M16	Involve asset managers during project design stage.	Involve asset managers in design
M17	Tenant demand and involvement during project design stage.	Tenant involvement in design
M18	Provide suitable insulation.	Suitable insulation
M19	Effective control strategy.	Effective control strategy
M20	Improve system design.	Improve system design
M21	Government should make definite policies with clear objectives.	Definite policies with clear objectives
M22	Local authority should inform its clients of any available incentives.	Inform clients of available incentives
M23	Establishing one system that addresses the different tools and models for green building accreditation.	Unified accreditation system
M24	Government needs to be ahead of the industry in awareness and information on EERTs.	Government ahead of industry
M25	Vote for a visionary and strong government.	Vote in appropriate government
M26	Apply green leases.	Green lease

Appendix 9 (*continued*) - Results of Interview Data Analysis: Managing Measures of EERTs Critical Risks

Code	Measures to manage the critical risks of EERTs	Abridged names
M27	Better feed-in tariff policies.	Feed-in tariff policies
M28	Marketing and consumer education.	Marketing and consumer education
M29	Implement funding schemes.	Special purpose funds
M30	Government provide extra and adequate incentives.	Extra financial support
M31	Set policies that can be open for review in the future in set periods by the public and professionals.	Policies to be open for future review
M32	Provide incentives for EERTs that reduce public infrastructure loads.	Incentives for reduced public infrastructure loads
M33	Establish a contingency plan for EERTs.	Contingency plan
M34	Move from an individual building basis into a whole environmental system basis.	Encourage a whole environmental system
M35	Extended warranties by EERT suppliers and contractors.	Extended warranties
M36	Time and market forces	Time and market forces

Appendix 10 – Results of Interview Data Analysis: Managing Stakeholders Number of Times Mentioned by Interviewees

Critical risks	Managing stakeholders										
	All stakeholders	Architect	Contractor	Engineer	Facility manager	Government	Industry experts	Occupier	Owner/ developer	Project manager	Supplier
Emergence of new and superior technology	1	3		8						2	3
Future change in regional climate and weather fluctuation	1	1		5		2	1				
Hidden costs				5					3	7	1
Lack of access to funds	1			1		1			4	4	
Lack of skilled personnel	2		1	2		1	4		1	2	2
Low consumer demand and acceptance			1	5		1					4
Misplaced incentives	1					4		3	2	5	
Noise and building vibration		2	1	5						1	3
Presence of system constraints	2			7	1	3			2	2	3
Slow response rate to temperature changes			1	7				1	2		1
Surface condensation and mould growth		1		6	2				1		
Uncertain availability of incentives		1		1		3		1	1	4	1
Uncertain government policies	5		1	2		6		2	2	2	
Uncertain payback period	4			4	3	2		2		2	
Total	17	8	5	58	6	23	5	9	18	31	18

Appendix 11 – Results of Interview Data Analysis: Critical Risks and Lifecycle Stages: Number of Times Mentioned by Interviewees

Critical risks	Lifecycle stages of action				
	Throughout the lifecycle	Concept stage	Design stage	An industry issue that should be addressed as soon as possible	Operation and maintenance stage
Emergence of new and superior technology		5	8		
Future change in regional climate and weather fluctuation	1	6	3		
Hidden costs		7	5		3
Lack of access to funds		5	2	3	
Lack of skilled personnel		5		9	
Low consumer demand and acceptance			6	3	
Misplaced incentives		7	4	2	
Noise and building vibration			8		
Presence of system constraints	1	6	7		
Slow response rate to temperature changes			6		1
Surface condensation and mould growth	2		5		2
Uncertain availability of incentives		4	2	5	
Uncertain government policies		4	4	9	
Uncertain payback period	4	5	3		3
Total	8	54	63	31	9

Appendix 12 – Case Study

Part A

1. Apply the framework on the technologies that are implemented in the selected green office building.

2. Please give your comments on the proposed framework.

3. Please give any additional information from your practical experience that can be useful if added to the framework, such as unidentified critical risks or managing measures.

Part B

Please use the Likert scale (see Table 1) to express your opinion on the following characteristics of the framework:

1.	The framework is clear and easy to use	1	2	3	4	5
2.	The framework is useful and effective	1	2	3	4	5
3.	The framework is comprehensive	1	2	3	4	5
4.	Overall opinion on the framework	1	2	3	4	5

Table 1: Likert scale

Likert level	Points
Strongly agree	1
Agree	2
Neither agree or disagree	3
Disagree	4
Strongly disagree	5

Appendix 13 – Results of Case Study Data Analysis: Council House 2 building

Framework step	Feedback
Communication and consultation	According to the CH2 project manager, the presented material for this step was found to be sufficient.
Establish the context	According to the CH2 project manager, the presented material for this step was found to be sufficient.
Identification	• *Chilled beams, radiant systems, underfloor air distribution, night purge and natural ventilation, photovoltaic panels, solar thermal systems, wind turbines:* According to the CH2 project manager, the information provided for the above EERTs, including the critical risks, affected stakeholders, and lifecycle stages of occurrence, were found to be appropriate. • *Energy efficient light bulbs:* For the critical risk *presence of system constraints,* it was found that the stakeholder affected is the occupier, and the lifecycle stage of occurrence is operation. • *Motion sensors:* For the critical risk *presence of system constraints,* it was found that the stakeholder affected is the occupier and the lifecycle stage of occurrence is operation.
Risk analysis and evaluation	• *Chilled beams, radiant systems, underfloor air distribution, solar thermal systems:* No critical risks identified in the context of CH2 for the EERTs above. • *Night purge and natural ventilation:* Two risks were identified: Future change in regional climate and weather fluctuation and slow response rate to temperature changes. 7. Analysis of the two previously selected critical risks was as follows: * Future change in regional climate and weather fluctuation, likelihood = 3, consequence = 2, level of risk = 6. * Slow response rate to temperature change, likelihood = 3, consequence = 2, level of risk = 6. 8. All risks require treatment as they have medium levels of risks. 9. Treatment prioritization was as follows: 1= Slow response rate to temperature changes, 2= Future change in regional climate and weather fluctuation. • *Energy efficient light bulbs:* One risk was identified, that is presence of system constraints. 6. Analysis was as follows: * Presence of system constraints, likelihood = 4, consequence = 3, level of risk = 12. 7. The risk requires treatment because it is of critical level of risk. • *Motion sensors:* One risk was identified, that is presence of system constraints. 4. Analysis was as follows: * Presences of system constraints, likelihood = 4, consequence = 3, level of risk = 12. 5. The risk requires treatment because it is of critical level of risk.

Appendix 13 (*continued*) – Results of Case Study Data Analysis: Council House 2 building

Framework step	Feedback
Risk analysis and evaluation (*continued*)	• *Photovoltaic panels:* One risk was identified, that is uncertain payback period. 3. Analysis was as follows: * Uncertain payback period, likelihood = 3, consequence = 2, level of risk = 6. 4. The risk requires treatment because it is of medium level of risk. • *Wind turbines:* Four risks were selected as applicable to wind turbines: 1. Emergence of new and superior technology, 2. Future change in regional climate and weather fluctuation, 3. Lack of access to funds, and 4. Uncertain payback period. 4. Analysis of the four selected critical risks was as follows: * Emergence of new and superior technology, likelihood = 4, consequence = 3, level of risk = 12. * Future change in regional climate and weather fluctuation, likelihood = 3, consequence = 2, level of risk = 6. * Lack of access to funds, likelihood = 4, consequence = 3, level of risk = 12. * Uncertain payback period, likelihood = 4, consequence =3, level of risk = 12. 5. All risks require treatment as they have medium to critical levels of risks. 6. Treatment prioritization was as follows: 1=Uncertain payback period, 2=Emergence of new and superior technology, 3=Lack of access to funds, and 4=Future change in regional climate and weather fluctuation.
Treatment	• *Chilled beams, radiant systems, underfloor air distribution, night purge and natural ventilation, photovoltaic panels, solar thermal systems:* According to the CH2 project manager, the presented managing measures for the EERTs above were found to be helpful and adequate. • *Energy efficient light bulbs* and *motion sensors:* To resolve the risk of presence of system constraints for both mentioned EERTs, the action taken by the building stakeholders was to appoint knowledgeable skilled personnel to re-implement and repair the technologies. This corresponds to the two proposed managing measures by the framework, which are: (1) Share information and knowledge among industry practitioners, and (2) Provide training and education for EERTs project teams. The building project manager also believed that the other managing measured provided in the framework are adequate and helpful. • *Wind turbines:* For the three critical risks identified, no managing measures were taken by the building stakeholders. The wind turbines were suspended from operation and discussion is carried on replacing them. The project manager reviewed the proposed managing measures provided in the framework and believed they are adequate and helpful specifically as pre-cautious measures for those projects which are still in concept and design stages.
Monitor and review	According to the CH2 project manager, the presented material for this step was found to be sufficient.

Appendix 14 – Results of Case Study Data Analysis: Pixel Building

Framework step	Feedback
Communication and consultation	According to the Pixel ESD engineer, the presented material for this step was found to be sufficient.
Establish the context	According to the Pixel ESD engineer, the presented material for this step was found to be sufficient.
Identification	• *Radiant systems, night purge and natural ventilation, energy efficient light bulbs, motion sensors, wind turbines:* According to the CH2 project manager, the information provided for the above EERTs, including the critical risks, affected stakeholders, and lifecycle stages of occurrence, were found to be appropriate. • *Photovoltaic panels:* For the critical risk *hidden costs,* it was found that the stakeholder affected is the engineer. • *Underfloor air distribution:* For the critical risk *presence of system constraints,* it was found that the stakeholder affected is the contractor.
Risk analysis and evaluation	• *Radiant systems, night purge and natural ventilation, energy efficient light bulbs, motion sensors:* No critical risks identified in the context of Pixel for the EERTs above. • *Underfloor air distribution:* Two risks were identified: Lack of skilled personnel and presence of system constraints. 10. Analysis of the two previously selected critical risks was as follows: * Lack of skilled personnel, likelihood = 4, consequence = 4, level of risk = 16. * Presence of system constraints, likelihood = 3, consequence = 2, level of risk = 6. 11. All risks require treatment as they have medium and critical levels of risks. 12. Treatment prioritization was as follows: 1 = Lack of skilled personnel, 2 = Presence of system constraints. • *Photovoltaic panels:* Five critical risks were identified: Emergence of new and superior technology, hidden costs, misplaced incentives, uncertain availability of incentives, and uncertain government policies. 8. Analysis was as follows: * Emergence of new and superior technology, likelihood = 5, consequence = 3, level of risk = 15. * Hidden costs, likelihood = 3, consequence = 2, level of risk = 6. * Misplaced incentives, likelihood = 5, consequence = 3, level of risk = 15. * Uncertain availability of incentives, likelihood = 4, consequence = 3, level of risk = 12. * Uncertain government policies, likelihood = 4, consequence = 3, level of risk = 12. 9. All risks require treatment as they have medium and critical levels of risks. 10. Treatment prioritization was as follows: 1 = Emergence of new and superior technology, 2 = Misplaced incentives, 3 = Uncertain availability of incentives, 4 = Uncertain government policies, 5 = Hidden costs.

Appendix 14 (*continued*) – Results of Case Study Data Analysis: Pixel building

Framework step	Feedback
Risk analysis and evaluation (*continued*)	• *Wind turbines:* Six critical risks were identified: Emergence of new and superior technology, future change in regional climate and whether fluctuation, hidden costs, lack of skilled personnel, misplaced incentives, uncertain payback period. 6. Analysis was as follows: * Emergence of new and superior technology, likelihood = 4, consequence = 3, level of risk = 12. * Future change in regional climate and whether fluctuation, likelihood = 3, consequence = 3, level of risk = 9. * Hidden costs, likelihood = 3, consequence = 2, level of risk = 6. * Lack of skilled personnel, likelihood = 3, consequence = 4, level of risk = 12. * Misplaced incentives, likelihood = 4, consequence = 3, level of risk = 12. * Uncertain payback period, likelihood = 3, consequence = 2, level of risk = 6. 4. All risks require treatment as they have medium and critical levels of risks. 5. Treatment prioritization was as follows: 1 = Emergence of new and superior technology, 2 = Lack of skilled personnel, 3 = Misplaced incentives, 4 = Future change in regional climate and whether fluctuation, 5 = Hidden costs, 6 = Uncertain payback period.
Treatment	• *Radiant systems, night purge and natural ventilation, energy efficient light bulbs, motion sensors:* According to the Pixel ESD engineer, the presented managing measures for the EERTs above were found to be helpful and adequate. • *Underfloor air distribution* For resolving the critical risks lack of skilled personnel and presence of system constraints, the building stakeholders' reappointed people to carry on the job required. • *Photovoltaic panels:* • Similarly to the issues identified with the *underfloor air distribution system,* skilled personnel were hired to fix issues and perform the job required. • *Wind turbines:* Technical issues occurred with the wind turbines due to the lack of skilled personnel. The building stakeholders aim to resolve these technical issues by appointing skilled personnel.
Monitor and review	According to the Pixel ESD engineer, the presented material for this step was found to be sufficient.

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